RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXVIII.

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THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1895. [February.

Geological Survey of India and of

ERRATUM.

RECORDS, GEOLOGICAL SURVEY OF INDIA, VOL. XXVII, PART 4.

Map facing page 115, the scale should be 1"=4 miles instead of 1"= 16 miles.

Middlemiss, Madras; Dr. H. Warth, Madras; Mr. P. N. [illegible]
Mr. T. H. Holland and Dr. F. Noetling at Head-Quarters.

At the beginning of the present field-season the officers of the department were distributed as follows:—

Mr. R. D. OLDHAM and „ DATTA	Rewah.
Mr. LATOUCHE and LALA HIRA LAL	Sukkur.
Mr. P. N. BOSE	Central Provinces.
„ MIDDLEMISS	Madras.
„ HOLLAND	Head-Quarters.
„ SMITH	Baluchistán.
Dr. NOETLING	Upper Burma.
Mr. ANDERSON	Chota Nagpore.

Summary of work accomplished.

In the following notes will be found an outline of the work done during 1894.

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Part 1.] 1895. [February.

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1894.

Staff of the Survey.

Dr. William King retired from the Directorship on the 16th July last, after a total length of service of 37 years, seven of which were passed as Director. His services are briefly noticed in the Records, Vol. XXVII, page. 109.

Mr. T. W. H. Hughes was compelled to retire from the 17th October, owing to an unfortunate accident, which has deprived him of his eyesight.

Mr. W. B. D. Edwards, having obtained an appointment as Inspector of Schools in England, has resigned his appointment from the 4th November 1894.

The vacancies thus created will be filled in due course by men selected by Her Majesty's Secretary of State.

Mr. William Anderson was appointed by the Secretary of State to be Mining Specialist on the Survey, and joined the Department on the 15th November 1894.

At the beginning of the year 1894, the officers of the department not on leave were disposed as follows :—

Myself with Mr. F. H. Smith and Lala Kishen Singh in Baluchistán; Mr. T. H. D. La Touche in charge of boring at Sukkur; Mr. P. N. Bose, Rewah; Mr. C. S. Middlemiss, Madras; Dr. H. Warth, Madras; Mr. P. N. Datta, Central Provinces; Mr. T. H. Holland and Dr. F. Noetling at Head-Quarters.

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In the following notes will be found an outline of the work done during 1894.

Rewah.
P. N. Bose.
R. D. Oldham.
P. N. Datta.

During the season of 1893 to 1894 Mr. Bose surveyed a rather extensive area in Rewah and the ground east of it, in all more than 2,000 square miles, of which, however, some parts had already been reported on by Mr. Smith and Kishen Singh, who were attached to the party under Mr. Hughes in 1893. Mr. Bose distinguishes the following formations in descending order:—

4. Gondwanas.
3. Vindhyans.
2. Transitions.
1. Metamorphics.

and amongst the intrusive rocks: granite and diorite.

He separates a schistose formation from the transitions proper, *i. e.* the representatives of the Bijáwar system, and includes a belt of gneissose rocks amongst the former, being probably the result of local metamorphism of the schistose series by the intrusive granites. The lower vindhyans rest unconformably on the transitions.

Mr. Oldham has taken over charge of the Rewah survey this field-season, with Mr. Datta to assist him; he has since had an opportunity of inspecting Mr. Bose's work, and has come to the conclusion that the so called "gneiss" of Mr. Bose is in reality an intrusive granite. Mr. Oldham has not yet been able to confirm the separation of the schistose beds from the transitions. If the "gneiss" is only intrusive granite, it seems very probable that the difference in lithological character between the schistose and transition series is due to contact metamorphism. Mr. Bose describes the two series of rocks as conformable and renders their position in this manner in his section.

I myself crossed this belt of transition rocks further eastwards some years ago and was struck at that time with the general resemblance of the series with the great thickness of beds which underlie the lower silurian of the Himálayas, which I had comprised under the name of the haimantas and of which the upper portion may possibly he correlated with the cambrians. I still believe that this series of transitions underlying the lower vindhyans will turn out to be an equivalent of the haimanta group of the Himálayas.

Mr. Datta is working at the lower vindhyans north of the Sone and has been able to examine some sections in greater detail, but so far Mr. Oldham suspects that the lower vindhyans (so-called) belong to a different and unconformable series to the vindhyans proper in which opinion he differs from Mr. Mallet. (See Vol. VII of the Memoirs.)

Central Provinces.
P. N. Datta, 1893-94.
P. N. Bose, 1894.

Mr. Datta had been posted to the Bhandara District during the previous field-season, and he was engaged at the beginning of 1894 on the geological survey of part of a still unknown ground in the Central Provinces. He managed to go over two separate areas, namely, part of the valley of the Kanhun river in Nagpur and Chindwara, and secondly, parts of the Bhandara district. In the first-named district he came across a crystalline and schistose series with intrusions and spreads of igneous rock, which is unconformably overlaid by lameta beds; the latter proved unfossiliferous.

In the second or Bhandara area Mr. Datta observed crystalline rocks with

transition beds, the series forming the western extension of the Chattisgarh basin. A number of sections were examined in detail, but until the rock-specimens can be examined microscopically, not many new facts can be made out regarding the structure of that part of India. Mr. Datta has brought back a fine collection of hand-specimens for the museum.

At the beginning of last field-season Mr. Bose was posted to the same ground, and he started work in continuation of the surveys of Dr. King in the Chattisgarh division. He believes to have met with confirmatory evidence in favour of the unconformable superposition of certain beds over the Chilpi Ghât series, which may possibly represent lower vindhyans in this area. It is a point, however, which will require much clearer evidence before this view can be finally adopted. It is directly opposed to both Mr. Medlicott's and Dr. King's views (for the latter see Records, Vol. XVIII, p. 190).

Madras.
Mr. C. S. Middlemiss.
Dr. H. Warth.

During December 1893, Mr. Middlemiss was transferred to the Madras Presidency, where he began a detailed investigation of the mineral resources and petrology of the Salem district, with special reference to the occurrence of corundum.

During the first few months of 1894, a cursory examination of the ground was only made, but nevertheless some very valuable observations were the result; he came to the conclusion that the corundum is not an original mineral constituent of the gneissose rocks in which it occurs, but is the result of a mineral change or metamorphism of the matrix rock. He infers this from the patchy way in which it occurs, from the zone, or shell of carbonate of lime and of quartz (at Sithampundi), and from the similar shell of pink felspar enclosing the corundum crystals in the Paparapatti rock. The general aspect is, as if it had segregated out in certain places, leaving an enclosing lenticular patch of altered gneiss and an envelope of another mineral behind. This field-season Mr. Middlemiss is provided with the necessary outfit for a microscopic examination of the rocks, and we may expect a large addition to a more exact knowledge of the petrology of Madras, which, it is to be hoped, will eventually form a useful and more or less complete guide to the crystalline rocks of India. He divides the Salem rocks provisionally as follows:—

Crystalline gneissic rocks—

(1) White and grey quartzo-felspathic	rocks.
(2) Purple and grey biotite gneissic	do.
(3) Hornblende gneissic	do.
(4) Hypersthene gneissic	do.

The above, though mutually interbanded in places, also predominate individually over certain areas. Hence they may be separated when traversing from East to West:—

(a) The Morappur	band of	hornblende	gneissic	rocks.
(b) The Mukhunur	„	hypersthene	„	„
(c) The Dharmapuri	„	quartzo-felspathic	„	„
(d) The Paparapatti	„	biotite	„	„
		with corundum.		

Foliation of the above varieties seems to be genuine, consisting of (1) layers of different width, often contorted, composed of different minerals, and combinations of minerals, (2) layers of different degrees of coarseness of grain. The rocks are not as a rule fissile to any extent along the foliation.

Intrusive rocks—

(A). Purple granites are non-foliated massive rocks, occurring sparsely and are intruded along foliation of gneissic rocks. They often include large pieces of hornblendic rocks.

(B). Dark traps, doleritic, composition augite and plagioclase, non-foliated, tough, massive dyke rocks, crossing the foliation of the gneissic rocks at right angles; fairly numerous, but difficult to trace far, except locally.

The cretaceous rocks of Pondicherry; Dr. H. Warth.

It was desirable to study the cretaceous beds of Pondicherry in greater detail, and collect therefrom good material for description; Dr. Warth was deputed to do so, and he devoted the field-season of 1893-94 to this task.

The fossils which were collected by Dr. Warth are somewhat dissappointing, both as regards numbers and preservation, but they have been sent to Dr. Kossmat of the Vienna University, who is also engaged on the determination of the collection of cretaceous fossils from Trichinopoly belonging to the Madras Museum. From a preliminary note which this gentleman has sent it appears that the entire series of Pondicherry beds belongs to the Ariyalur group of Southern India.

Himálayas. Mr. T. H. Holland.

It will be remembered that a landslip occurred early in September 1893 and dammed up the Birahi Ganga which drained 90 square miles above Gohna. The locality was examined by Mr. Holland early in March 1894, when the lake was nearly 3 miles long with a maximum width of 1 mile. Mr. Holland's report described (1) the geographical and geological features of the Birahi Ganga valley, (2) a description of the landslip and lake, and (3) a discussion of the causes which led to the landslip.

With regard to the second point he predicted—

(1) That the lake would be full and would overflow the barrier about the middle of August.

(2) That the dam was strong enough to resist the pressure of the water before overflow.

(3) That after overflow the lake would be reduced to one about 3½ miles long, and that this would remain permanent for some time.

(4) That landslips would occur into the lake.

The lake overflowed the dam early on the morning of August 25th, the stream flowing down the steep slope to the bed below Gohna. The erosion thus continued until late at night, when a channel having been cut back to the lip of the lake rapid recession of levels followed until the erosion was checked by reduction of the slope and exposure of large blocks of dolomite, by removal of the fine detritus forming the upper part of the dam. The lake left is about 3 miles long and over 300 feet deep, with, according to the latest accounts, every chance of being historically permanent, although its gradual destruction by silting up of the basin and gradual erosion of the dam will, geologically considered, happen at no distant time. The landslips which have occurred into the lake have with the silt raised the bottom nearly 100 feet. The dam is now quite firm and the outlet through the gorge cut in its upper part is over a rocky bed with a slope of about 1 in 15.

In this gorge, cut through a portion of the first of the two main falls, there are exposed, according to Lieutenant Crookshank, R.E., great bundles of strata dipping towards the south at an angle of about 50°, which he regards as a striking confirmation of Mr. Holland's conclusion with regard to the peculiar character of the first

slip in which Mr. Holland considered that the hill must have pitched forward and not have slipped down in stream-fashion after the manner of smaller and more common landslips. (Records, Vol. XXVII, page 59.)

Punjáb.
Dr. F. Noetling.

The alarming increase of accidents in the Dandote coal-mines made an immediate inspection of the Dandote (Punjáb) and Warora (Central Provinces) collieries desirable; the Inspector of Mines in India had not been appointed then (October 1893), and Dr. Noetling was therefore deputed on this duty. In addition to this inspection, Dr. Noetling was able to add to our knowledge of the older palæozoic strata of the Salt-Range. He has since published his observations in a paper in the Records, Vol. XXVII, pages 71 to 86, which clears up many discrepancies in the Salt-Range geology.

Mr. Wynne, who described the geology of that range in greater detail, was the first observer who insisted on the age of certain beds as older than carboniferous and to be quite distinct from the latter. On the strength of Dr. Waagen's determination of the few fossils which had then been found, these beds were considered to be of silurian age. Later on Dr. Waagen combated this view and claimed a lower carboniferous age for these beds, but modified this opinion as cambrian trilobites were found, whilst his work, Vol. IV of Ser. XIII of the Palæontologia Indica, was in progress.

Dr. Noetling, who had studied the Khusak section carefully (already well described by Mr. Middlemiss, Records XXXIV, page 24) now divides the cambrian system of the Salt-Range as follows, in descending order:—

4. Bhaganwalla group, or salt-crystal pseudomorph zone.
3. Jutana group, or Magnesian sandstone.
2. Khussak group, or Neobolus beds.
1. Khewra group, or Purple sandstone.

Each of which divisions he further sub-divides.

The fossils which he has found, have been forwarded to Dr. Waagen for determination.

Sukkur boring.
Mr. T. D. La Touche.
Lala Hira Lal.

The boring for petroleum which has been put down at Sukkur on the Indus has steadily progressed, and it has been sunk to a depth of 957 feet. Considerable difficulty is occasionally experienced, but not more than might have been anticipated. The practical result is so far *nil*, although signs of escape of gas have been observed at depths below 800 feet, which afford some slight hope of obtaining oil further down. But the boring is not without some geological interest, as it proves that the thickness of the strata is much in accordance with the estimate which I have given, which was practically taken from the Sharigh section. The lithological character of the beds passed through is very similar to that of the Sharigh section, and in some respects, particularly in the upper portion, very like the section near Khattan. As near Sharigh, so also at Sukkur, a great thickness of clays, alternating with thin limestone bands, and traversed by numerous gypsum veins and nests, occurs below the light coloured upper nummulitic limestone of Sukkur.

The boring ought to reach the carbonaceous horizon within the next 200 to 250 feet, if the section corresponds as closely with the Sharigh section, as seems likely.

Mr. La Touche reported in December 1894 that he had examined a spot about 8 miles south of Rohri, where the freshly broken soil emits a strong smell of petroleum, which may indicate the escape of oil below the thickness of alluvium. There is no rock *in situ* within miles of the spot, but the question is being investigated now.

Baluchistán.
C. L. Griesbach.
W. B. D. Edwards.
F. H. Smith.
Lala Kishen Sing.

Considerable progress has been made in the geological survey of Baluchistán, which is, perhaps, one of the most interesting countries in the world, from a structural point of view.

Mr. Edwards joined my party in the early part of the year and was told off to examine the so-called Quetta coal-area. Before he could quite finish the task, he became seriously ill, which led eventually to his retirement this year.

Mr. Smith joined my party in the autumn of 1893, and after continuing the work which Mr. Edwards had begun, brought it to a close during this year.

He accompanied me afterwards (Spring 1894) on a tour to the Mari country, which I undertook to study certain sections which Mr. Oldham had reported on previously (Records, Vol. XXV, pages 18 to 29). Mr. Smith was instructed to take up work in continuation eastwards of Mr. Oldham's surveys, and he has since geologically mapped some 2,000 square miles of very interesting country east and south-east of the sections which are reported on in the paper quoted.

Mr. Smith has shown considerable acquaintance with field-work, and has prepared a number of working sections, drawn to scale. These, with the map, will be published later on, when the survey of that country has been completed.

During November and December 1894, Mr. Smith continued his former work in the high hills east and south-east of Quetta, which have now all been examined, with the result of confirming in most cases my first conjectures, which I expressed in Memoir, Vol. XVIII, part 1. When I visited that country in 1880 a close study of the sections was impossible, owing to the disturbed state the frontier was in at that time, but I concluded from the general structure of the country, that the Takatu hill mass represented a section comprising both cretaceous and lower eocene strata; Dr. W. T. Blanford in his Memoir, Vol. XX, part 2, combated this view, having had better opportunities of studying this particular section. My view, however, has now been amply upheld by Mr. Smith's subsequent work, and not only have upper cretaceous rocks (with belemnites) been found to constitute the main mass of the Takatu hills, but also evidence has been produced of the presence of older (neocomian and jurassic) limestones with fossils. The uppermost portion of the hill-mass is lower nummulitic as represented in my memoir. A fault separates this section from younger eocene beds east and south-eastwards; this fault may be observed for some distance and forms one of the great structural features of Baluchistán.

Lala Kishen Singh was engaged in systematically collecting fossils from certain beds described by Mr. Oldham in the paper quoted above; in the end a very valuable collection of fossils has been brought together, which have since been examined and described by Dr. Noetling. The description will be published in the Palæontologia Indica as soon as the numerous plates can be lithographed; the manuscript is ready for the press.

The general result fully justified my original opinion that there is quite a sharp

division between the cretaceous and eocene strata. The examination of the fossils proved also the existence of a distinct neocomian and below it, of a jurassic horizon. A local unconformity occurs above the neocomian.

The section at Mazár Drik, which is merely a type of numerous similar sections, is as follows in descending order:—

Middle / Lower Eocene	6 Shales and sandstones. 5 Grey limestone beds with *nummulites*.
Upper Cretaceous	4 Calcareous grit, shales and limestone with an abundant fauna of *cephalopods*, *echinoids*, *corals*, *foraminifera*, etc. 3 *Belemnite* bearing series of shales and limestone beds.
	Local unconformity.
Neocomian	2 White and grey limestone with *belemnites*.
Upper Jurassic	1 Hard grey, thick-bedded limestone with a rich ammonite fauna.

In the spring of 1894, I instructed Kishen Singh to survey the area south and south-east of the Zarghún and south of the Harnai and Khóst hills on sheet 21-$\frac{SE}{4}$ of the Baluchistán survey, which he did satisfactorily,—in all 590 square miles.

I myself continued the work, which I had begun during the previous field-season; the ranges which divide the Quetta valley from the Pishin and the Kójak range were examined, and several traverses were completed, to settle the question of structure of these ranges. But there is still much to be done and it will require at least one more season's work to fill in the gaps on our geological map of the country west and north-west of Quetta. The first 4½ months of 1894 I devoted to the study and survey of the ranges which inclose the western Zhób valley, and especially the mass of hill-ranges between Loralai and Khanazai. This was a continuation of my previous field-season's work and the result is a fairly accurate geological survey of about 3,400 square miles, completed during the greater part of two seasons. In this part of Baluchistán, I could distinguish the following divisions of strata in descending order:—

Recent	(11) Alluvium; wide-spread deposits of sandy clays, conglomerates, and also in places, blown sands, which generally pass up imperceptibly from the next older formation.
Seistán formation Pleistocene	(10) Red and white sandy clays with sandstone and conglomerate beds, with much gypsum in layers and strings.
Miocene and pliocene	(9) Sandstone, shales, and conglomerate of the ordinary Siwalik type; fossil bones and casts of large *gastropods*.
Younger Eocene and Miocene	(8) Great thickness of sandstone beds, very like the Siwaliks in character, but with occasional limestone partings, which contain marine fossils.

Eocene.	Great development of basic igneous rocks. Intrusions of later date.	(7) Concretionary limestone and shales with fossils. (6) Sandstones, shales, and clay. (5) Thick limestone with *nummulites*.
Upper Cretaceous.	Interbedded basic rocks; gabbro, tufa.	(4) Limestone with *Sphenodiscus*, *Cardium Beaumonti*, etc., etc. (3) Shales and limestone with *belemnites*.
Neocomian		(2) Thick limestone with neocomian fossils.
Jurassic		(1) Massive limestone with jurassic fossils.

Along a great line of dislocation which runs along the Chinjan and Yusuf Kats valleys, I have met with what I must consider genuine "blocs exotiques,"—of carboniferous and triassic rocks, bearing fossils. The dislocation is characterized by intrusions of basic rocks which obscure the position of these "blocs." It is hoped that more evidence of the same will be forthcoming during the next field-seasons.

One of the most remarkable features of Baluchistán geology is the association or igneous rocks with the upper cretaceous and the lower and middle part of the eocene deposits. The first outburst of basic rocks, as far as can at present be ascertained, occurred in later cretaceous times; at least evidence of *intrusions* only have been met with in the jurassic beds, and even the lower part (limestones) of the upper cretacious seems free from interbedded igneous rock, but on the other hand these beds show locally great alteration near intrusions of the latter examples: Kach near Quetta, Gwál and other localities in the Zhób valley. The earliest evidences of contemporaneous igneous action occur in the upper cretaceous belemnite beds. This is seen clearest in the upper Zhób valley, especially near Gwál. Certain large areas of Baluchistán (south of Hindu Bágh and Kójak range) are entirely made up of great outbursts and spreads of basic igneous rocks, with gabbro and serpentine, associated with a few sedimentary beds, which are much altered in places and quite schistose in some. It is hardly possible to divide this complex of rocks, as precisely similar conditions seem to have continued right into middle eocene deposits. The higher portion of this facies, which may be compared to the Flysch formation of Europe, especially as developed in the Island of Elba,—contains a few beds of limestone which yielded *nummulites*, thus limiting the duration of igneous action to the period between the deposition of upper cretaceous and middle eocene beds. Quite unaltered limestone with upper eocene (Spintangi) fossils overlies the igneous facies of the northern Zhób and of the Kójak range. All trace of igneous action seems to have died out during that epoch.

The Kójak formation of shales, limestones and tuffaceous rocks,—in places quite schistose—I considered to be tertiary in 1880 (Memoirs, Vol. XVIII) and later in 1884 (Records, Vol. XVIII, page 59), as possibly cretaceous; probably both views are correct to some extent, and they may represent the igneous facies ranging from the upper cretaceous belemnite shales to middle eocene, and the formation may be a continuation westwards of the upper Zhób rocks. They are also associated with some irregular beds of limestone which contain large *nummulites*.

Connected with this great volcanic outburst are acid rocks, chiefly of the granitic family, which form part of the Khwája Amrán, and these may have been amongst the earliest eruptions which took place there.

Burma.
Baluchistán.
Dr. Fritz Noetling.

There are still a few questions of structural importance involved in the Yenangyoung oil-bearing tract and to clear up the same, Dr. Noetling was sent to Burma during this field-season. An exhaustive report on the oil-region will be brought out by him shortly.

During the hot weather and rains of last year Dr. Noetling examined and described the fine collection of cretaceous and jurassic fossils from Baluchistán which will be published as series XVI of the Palæontologia Indica.

Economic Geology.

During 1894, several officers were employed in practical investigations only, but in all cases where useful minerals were come across by the other parties engaged in field work, such occurrences have also been reported on.

Mr. LaTouche was during the past year, and is still, engaged in the trial boring for petroleum at Sukkur. Mr. Middlemiss has been engaged in the examination of the corundum and magnesite deposits of Madras.

Mr. Holland was employed in reporting on the Gohna landslip and has since been engaged in making numerous assays of minerals and rocks.

Mr. Smith surveyed the so-called "Quetta" coal-area, and has prepared a report which will be published. Dr. Fritz Noetling was deputed to report on the working of the Dandote and Warora coal-mines and has issued his reports on the same. He is now at Yenangyoung in Burma in order to finish his investigations of the oil-fields.

Mr. Grundy, the Inspector of Mines in India, has issued his first report for the year ending 1st July 1894, which has been printed and published. He has since inspected the mines in Mysore, Central Provinces and Rewah, and will proceed to Hyderabad (Dekkan), the Punjáb and Baluchistán.

Mr. William Anderson has been posted to Chota Nagpur to report on the supposed metalliferous belt of rocks.

Amongst the notes on useful minerals made by officers engaged in scientific surveys only, may be noticed reports by Mr. Bose on iron-ores, pockets of manganese, traces of copper and veins of argentiferous galena (61·60 per cent. lead and over 7 oz. of silver to the ton) in the Rewah State.

Mr. Datta reports on considerable quantities of an iron-ore in the Sone Valley, which is used locally for iron-manufacture.

Publications.

Considerable advance has been made in the publication of the Palæontologia Indica. Dr. Waagen has at last completed Vol. IV of series XIII, which deals with the ammonites of the ceratite beds of the salt-range. It is illustrated by 40 quarto plates and will appear shortly.

Series XV of the Palæontologia Indica has been commenced, and will illustrate the large and most important collection of fossils from the Himálayas, embracing not only the specimens preserved in the Geological Museum in Calcutta, but also every known specimen found in the Himálayas and preserved in the various European museums. Part 2 of Vol. II of this series is completed, and will appear shortly, illustrated by 31 quarto plates, descriptive of the Muschelkalk fauna of the Himálayas. Several other parts are in preparation.

Memoirs, Vol. XXV, on the geology of the Bellary district by R. B. Foote, is nearly ready for publication, and the final sheets are being passed for the press.

Vol. XXVI on the geology of Hazára by C. S. Middlemiss is in the press, and will appear shortly.

Vol. XXVII, Part 1 on the miocene fossils of Yenangyoung by Dr. Noetling, is in type and will shortly appear; Part 2 on the oil-fields of Yenangyoung is in manuscript, but will be ready for publication shortly after Dr. Noetling returns from Burma.

Museum and Laboratory.

Mr. Holland has re-arranged and labelled the collection of minerals to correspond with the more modern classification adopted in the new edition of Mr. Mallet's guide which has been re-written by Mr. Holland for the use of students. He also described a large number of rock specimens as contributions towards the work of classifying and arranging this portion of the collection. Where the description of the specimens has given promise of results of more than local petrographical interest, Mr. Holland has taken the opportunity of college vacations to work out their characters more fully in the field. In this way we have obtained a fairly comprehensive account of the distribution, and contact effects in the Bengal coal-fields of varieties of some new types of the remarkable group of peridotites. Amongst these the mica-peridotites which frequently contain anthophyllite and chromite are, from the excessive amount of apatite which they contain, most exceptional types amongst the known igneous rocks of the globe. The occurrence of these peridotites, which have now been found breaking through the lower Gondwana series in all the Bengal coal-fields, forms an interesting comparison with the peridotites which are similarly intrusive in the carbonaceous rocks of about the same age in South Africa. The large number of specimens of the peridotites and the altered and associated sedimentary rocks form a most instructive series in the Museum. In making this collection and in tracing out the field relations of the rocks, Mr. Holland has received most valuable help from Dr. Saise, Manager of the East India Railway Company's collieries at Giridih. (A detailed description of these rocks appears in Part 4 of Vol. XXVII of the Records).

Mr. Holland has described another new type of peridotite from the district of Manbhum which differs from previously known ones in containing hypersthene associated with olivine, augite, biotite and hornblende. (Records, Vol. XXVII, part 4.)

The mode of occurrence of the rare mineral columbite has been examined at Pananoa near Nawadih, East Indian Railway. Mr. Holland has found it in lumps imbedded in the quartz of a very coarse grained pegmatite dyke, intruded into a mica schist, which is crowded with tourmaline crystals.

The list of assays and determinations made in the laboratory has been published in the previous volume of the Records.

The work in the Museum was naturally interrupted during the early part of the year by Mr. Holland's absence at Gohna and Naini Tal, but he attributes the satisfactory progress which has been made largely to the valuable work done by the Museum Assistant, Mr. T. R. Blyth.

Whilst so much progress has been made in the mineral gallery of the Department, it is much to be regretted that the palæontological collection is in a most unsatisfactory state, both as regards arrangement of specimens and condition of the labels and cases. But this is entirely owing to the long absences of the Palæon-

tologist of the Survey, who for some years past has been engaged on entirely different work, such as reporting on the mineral resources of Burma and the inspection of collieries in India. But it is hoped that he will be able to devote himself to more scientific work in future. A good beginning has been made by him in describing the miocene fossils of Burma and the cretaceous collections from Baluchistán, and we may reasonably hope to get the Palæontological Museum into order during the next two years.
There is much need of an efficient Assistant in that branch of the Department.

Library. The additions to the library amounted to 1,756 volumes, of which 777 were acquired by presentation, and 979 by purchase.

C. L. GRIESBACH,
Director, Geological Survey of India.

CALCUTTA,
The 31st January 1895.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1894.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—John Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Bataviaasch Geonootschap van Kunsten en Wetenschappen.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
„ K. Preuss. Acad. der Wissenschaften.
„ K. Preuss: Geologische Landesanstalt.
BOLOGNA.—Reale Accademia delle Scienze dell' Istituto.
BOMBAY.—Meteorological Department, Government of Bombay.
„ Natural History Society.
„ Royal Asiatic Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
„ Society of Natural History.
BRESLAU.—Schlesische Gesellschaft fur Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australia.
„ Royal Society of Queensland.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Acad. Roy. des Sciences.
„ Société Belge de Geographie.
„ „ Roy. Malacologique de Belgique.
BUDAPEST.—Kön. Ungarische Geol. Anstalt.
BUENOS AIRES.—Acad. Nacional de Ciencias en Cordoba (Republica Argentina).
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
„ Asiatic Society of Bengal.
„ Editor, Indian Engineering.
„ „ The Indian Engineer.
„ Indian Museum.
„ Meteorological Department, Government of India.
„ Royal Botanic Garden.
„ Survey of India.
CAMBRIDGE.—Philosophical Society.
„ University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Verein für Naturkunde.
CHRISTIANIA.—Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Kong. Danske Videnskaberns Selskab.
DEHRA DUN.—Great Trigonometrical Survey.

DES MOINES.—Iowa Geological Survey.
DRESDEN.—Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
" " Dublin Society.
EDINBURGH.—Geological Society.
" Royal Scottish Geographical Society.
" " Scottish Society of Arts.
" " Society.
FLORENCE.—R. Biblioteca Nazionale Centrale di Firenze.
GLASGOW.—Glasgow University.
" Philosophical Society.
GOTHA.—Editor, Petermann's Geographische Mittheilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALLE.—Academia Cæsarea Leop.-Carol. Naturæ Curiosorum.
HAVRE.—Société Géologique de Normandie.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LEIDE.—École Polytechnique de Delft.
LEIPZIG.—Verein für Erdkunde.
LIÈGE.—Société Géol. de Belgique.
LILLE.—Société Géologique du Nord.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Museum.
" Geological Society.
" Iron and Steel Institute.
" Linnean Society of London.
" Royal Geographical Society.
" Royal Institute of Great Britain.
" Royal Society.
" Society of Arts.
" Zoölogical Society.
MADRID.—Sociedad Geografica de Madrid.
MANCHESTER.—Geological Society.
" Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
" Royal Society of Victoria.
MILAN.—Societá Italiana di Scienzé Naturali.
MOSCOW.—Société Imp. des Natur.
MUNICH.—Kon. Bayerische Acad. der Wissensch.
NAPLES.—Reale Accademia delle Scienze Fisfche e Matematiche.
NEWCASTLE UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, "American Journal of Science."
NEW YORK.—Academy of Sciences.
OXFORD.—University Museum.
OTTAWA.—Geological and Natural History Survey of Canada.
PARIS.—Editor, Annuaire Géologique Universel.
" Commission des Mines.

PARIS.—Ministere des Travaux Publics de la Carte Géologique de la France.
" Société de Geographie.
" " Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
" American Philosophical Society.
" Franklin Institute.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Scienze.
" " Comitato Geol. d'Italia.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Comité Géologique.
" Russische Mineralogische Gesellschaft.
SALEM.—Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch of the Royal Asiatic Society.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—L'Institut Royal Geol. de la Súede.
" Kongliga Svenska Vetenskaps Akademie.
SYDNEY.—Australian Museum.
" Department of Mines and Agriculture, New South Wales.
" Geological Survey of New South Wales.
" Linnean Society of New South Wales.
" Royal Society of New South Wales.
TOKIO.—Deutsche Gesellschaft für Natur und Volkerkunde.
TORONTO.—Canadian Institute.
TURIN.—Reale Accad. delle Scienze di Torino.
" Regia Universita di Torino.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissenschaften.
" K. K. Geographische Gesellschaft.
" K. K. Geologische Reichsanstalt.
" K. K. Naturhistorisches Hof-Museum.
WASHINGTON.—National Academy of Sciences.
" Smithsonian Institution.
" United States Geological Survey.
" " " Mint.
" " " National Museum.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
" Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Naturforschende Gesellschaft.
The Governments of Bengal, Bombay, India, Madras, and the Panjáb.
The Chief Commissioners of Assam, Burma, and the Central Provinces.
The Residents, Hyderabad and Mysore.

The Cretaceous Formation of Pondicherry by H. WARTH, D. SC., (Tübingen), *Deputy Superintendent, Geological Survey of India.*

The area which I was deputed to examine during January and February 1894, had last been visited by the late Mr. H. F. Blanford in 1860, and was described by him in Vol. IV, p. 156 of the Memoirs. It is situated between the Red Hills of Pondicherry on the south-east and between what Mr. Blanford called the Tirvukarai ridge on the north-west, and is bounded on the south-west by the alluvium of the Ariankupam river. The total length is about 8, and the width 4 miles. A large surface of this ground is occupied by numerous tanks or artificial reservoirs for rainwater, used for irrigation. Most of the area consists of level and cultivated fields, amidst which are a few isolated exposures of rock *in situ*. It is not nearly as favourable for study as are the cretaceous sections near Trichinopoly; there the exposures of strata on eroded patches measure square miles, whereas in the Pondicherry area they amount to acres or even square yards only. This great paucity of exposures has been repeatedly pointed out by Mr. H. F. Blanford, and if, notwithstanding this, the first explorers, Messrs. Kaye and Cunliffe obtained such large numbers of valuable fossils in 1840, it will be shown further on how this may be accounted for.

Mr. H. F. Blanford showed that the cretaceous strata may be separated into two distinct divisions: the lower he named the Valudayur group, which hitherto has been considered to be equivalent to the Utatur group of Trichinopoly, whilst the upper series he found to be identical with the Ariyalur group of Trichinopoly.

Considerable confusion has taken place in the collections made in Pondicherry, and the object of my visit to that area was not only to obtain a large number of fossils, but to establish them in the various horizons. I have succeeded not only in separating the fossils according to the two main divisions, but I have been able to distinguish three successive horizons in each of these divisions. We have, therefore, altogether 6 horizons from which fossils have been obtained, the three lower of which constitute Mr. H. F. Blanford's Valudayur group, whilst the three upper ones are what he accepted as Ariyalur group. As will be shown later on, the whole of the strata must now be considered as Ariyalur group.

The bedding of these horizons is either horizontal or a gently dipping towards south east. The general lithological character of all the beds is that of sand or sandy clay with calcareous nodules or concretions which are scattered throughout the whole formation. Only the uppermost horizon contains a continuous thin layer of limestone in addition to concretions.

Horizon A.

Horizon A is the lowest sub-division and appears on the surface as a strip 2 miles wide. It is separated from the Tirvukarai ridge by a band of alluvium 1½ miles wide which conceals all outcrops. Going from north-west to south-east, the first indication of the horizon consists of white sands with nodules of one foot thickness. These nodules or concretions contain traces of annelid channels only. They are also stained with dendritic manganese. The localities examined are well-exacavations, ½ mile east-south-east of Lingaredipaliam and 1 mile north-east of Katarampokam.

Next in ascending order we observe yellow sands with gravel, 1 mile east-

north-east of Katerikupam in the bed of the canal, and in the ravine 1 mile north-east of Vanur. The latter place is referred to by Mr. H. F. Blanford on page 157 of his Memoir.

Lastly, we have sandy clays with large concretions, which contain; annelid casts, they have a diameter of ¼ inch, and some were up to 6 inches in length. They are usually curved. The concretions consist of crystalline calcite with a distinctly botryoidal surface. They are usually somewhat lenticular, 2 feet thick, and of 3 feet diameter. I have searched for them in vain in the neighbourhood of the Ariankupam between Valudayur and Muterampatu, but the concretions are well exposed at the following three localities which are on the same strike, from south-west to north-east:—The first is near Katerikupam, where the concretions show along a length of over ½ mile of the canal excavation. The blocks had about 2 feet diameter and the surfaces were decidedly botryoidal, proving their concretionary origin. The second locality is about ¾ miles south-west of Vanur; the concretions are shown very clearly in several square wells. They form layers which have a slight inclination towards the south-east. Many of the lenticular concretions had about 1½ feet thickness and 3 feet diameter with botryoidal surfaces. In one well were so many concretions and so close together that they presented the appearance of a continuous bed of limestone, 2 feet thick. The concretions contain numerous annelid burrows. I broke up one of the blocks entirely without finding a trace of any fossil. In the neighbouring fields were also scattered blocks of the same kind. Near the village of Wattai close by, is a large square tank which is lined with the same blocks said to have been derived from the excavated tank bed. Many blocks of the concretions from horizon A are also seen in the lining of other tanks in the neighbourhood, for instance at Vanur. But in the latter many stones had been used, which must have been brought from near Saidarampet in French territory, and belong possibly to horizon E, and are usually fossiliferous. It is not easy to distinguish always the different blocks from each other. But those from horizon A have no fossil shells and are botryoidal, whilst certain fossils show others at once to have been derived from horizon E. The third place is the best of all the exposures. It is immediately south of the village of Andipaliam, where many concretions are exposed on the surface. One of them was 2 feet by 4 feet by 6 feet. The concretions formed layers with a moderate dip to the south-south-east, many of them were also washed out of the matrix, but most probably are very near their original site. Some of the concretions contained quartz pebbles about 2 inches in length arranged in layers.

I observed also some concretions about half a mile south-east of Olundiapati, in which I have not found any fossil, but which I am inclined to include in horizon A.

Horizon B.

The next higher horizon B contains fossiliferous concretions and has also yielded some fossils from the sandy matrix. I include herein the exposure of yellow sands in a tank-bed, 1 mile south-east of Vanur. At that place I found many minute bivalves and a few distinct *Baculites vagina*. On the Vanur Pondicherry road, 1 mile north of Saidarampet, small bivalves occur in a white sand, which I include in B, although it is in contact with scattered blocks of horizon E. I also include with B large, slightly fossiliferous concretions and nodules, 1 mile south-south-east of Pulichapaliam. In the road ditch and in

some wells east of the road, I found fossiliferous concretions of large size, of which one has yielded a small *ammonite*.

Horizon C.

Horizon C is the most important of all, as it seems most probable that from it were derived the cephalopods which Messrs. Kaye and Cunliffe obtained about the year 1840. The spot from which most of these fossils appear to have come is north-north-east of Valudayur and north of Tutipet. It is from this place that I obtained the best fossils of horizon C, but some I found further north-east close to the village of Rantankuppam. I found in this horizon four small *ammonites*, several species of *Hamites*, *Baculites vagina* in numerous well preserved specimens, many *lamellibranchiata*, *gastropoda*, etc. The list at the end of this paper refers to preliminary identifications by Dr. Kossmat.

The fossils occur in blocks which are not *in situ*, but washed out of the alluvia ground, and are largely used for building purposes, so that the supply is really limited. I have now used up all the loose blocks which I could see, and I doubt whether more will be found for a considerable time to come. Mr. H. F. Blanford considered the place already exhausted, as will be apparent from his remarks on pages 154, 155, 156, 158, 163, Memoirs, Vol. IV, and page 2 of his account of Cretaceous Cephalopoda in the *Palaeontologia Indica*.

Mr. Blanford referred at some length to the ridge east of Valudayur on which he traced the boundary between his Valudayur group and the overlying Ariyalur group. This ridge is not a very prominent object in the landscape, and some of the exposures on it, which Mr. H. F. Blanford described, must since have disappeared. If the Topographical Survey map had been provided with contour lines, this ridge as well as the Tirvukarai and Red hills ridges would be clearly shown, but although this is not the case, the ridge in question is marked by the space which it occupies between two rows of irrigation tanks, and a line drawn on the map from Tutipet to Akasampatti travels along the centre of the ridge. It rises about 115 feet above the sea and thus about 45 feet above the cretaceous area to the north-west of it and 89 feet above the level of the great Usteri tank lake to the south-east. Near Tutipet and Valudayur, the north-west base and part of the slope of the ridge comprises horizon C. Towards north-east the ridge merges more or less into the more elevated country, and the exposure of horizon C near Rautankupam is on nearly level ground. As will be seen hereafter, the south-east slope of the ridge about Tutipet, Karasur and Saidarampet coincides with the harder beds of the horizon F, and it is very probable that these limestone banks have been the cause of the preservation of the ridge.

Horizon D.

The horizon D is characterized by a continuous bed of sandy shale, several feet thick, which is full of casts of shells, most of them those of *lamellibranchiata*, *Trigonoarca Galdrina*, *Macrodon Japeticum*, *Alectryonia ungulata*, etc. Others will be found on the list at the end. I also found a few *ammonites* and *Baculites vagina* and some specimens of *nautilus* two feet in diameter. A few specimens of *terebratula* were also found in this horizon, also some *corals* and *echinoidea*. Small fish teeth were numerous.

A fact of importance is the wholesale conversion of shells into phosphate, or rather the production of interior casts of shells consisting of rich black phosphate.

Some of the casts show also the impression of honey-combed cells one-fiftieth of an inch in diameter, most likely due to bryozoa. In this same stratum are also numerous concretions of light brown colour, which are likewise strongly phosphatic; they are of irregular shapes, resembling some organic structure.

I found three very clear exposures of this horizon. The first in a well, a quarter of a mile west-south-west of Tutipet, the second is *in situ* on the surface of the road a quarter of a mile north of Karasur, the third is in a well a quarter of a mile west of Rautankupam on the west side of the Tindivanam Pondicherry road. A small exposure was also noted in a well, a quarter of a mile north-west of Royapudupakam. In the Rautankupam well the sandy bed, which contains the casts of shells, is also partly replaced by concretions of one foot thickness, in which fossils occur.

Phosphatized shells are not found in any of the other horizons, with the exception of the lowest portions of horizon E. There are some phosphatic cores of light color in the centre of gastropods, in nodules of the upper part of horizon F. But these cores are of quite different appearance to the phosphatic matter in D, and in much smaller quantity. The black phosphatized shells are a sure indication of horizon D and the overlying portions of horizon E. They are seen in several places scattered over the fields mixed with other fossils, where no distinct exposures of the strata are otherwise seen.

Horizon E.

This horizon is important on account of the large number of nodules of shell limestone it contains. A very great number of the nodules have been utilized for tank revetments and buildings in the neighbourhood. Many were also used for walls, buildings and pavements in Pondicherry. The pavement shows all the various fossils of the horizon in sections. One fossil is especially very prominent and characteristic. It is a coral, *Cyclolites filamentosa*, which is seen in semicircular sections. *Exogyra ostracina* is also common. Owing to the systematic removal of blocks from the surface of the outcrop, it is generally difficult to trace the area of horizon E, but at a place near Karasur I still saw the blocks being quarried, and one very large deposit of blocks is exposed *in situ*. There is also an outlier of this deposit consisting of some 40 blocks, at a point 1 mile north of Saidarampet. The worn surfaces of the blocks show sections of numerous fossils, which contrast strongly against the brown matrix. Besides *gastropoda* and *lamellibranchiata* in great numbers, the sections also show the semicircular or crescent shaped outlines of *Cyclolites filamentosa*, which coral is most characteristic of horizon E.

The wall of a tank near the village of Royapudupakam yielded numerous fossils as has already been pointed out by Mr. Blanford. Amongst them I collected *Exogyra ostracina*, *Alectryonia ungulata*, *Euptycha larvata*, *nautilus*, *etc.* Some of the fossils are also found in horizon D and with them were also some black phosphatic nodules.

Horizon F.

The uppermost horizon is characterized by fucoid casts, which are cylindrical and about three quarter of an inch thick and generally in broken pieces of about five inches length; some of these casts are bifurcated. They are much used for lime burning, along with calcareous nodules found in the same bed. The latter are about two inches diameter and

contain spiral *foraminifera* of minute size; they are dug up from the soil which overlies some of the fucoid limestone.

The same yellow, crystalline, somewhat sandy limestone was found exposed at the Usteri canal, one mile south-south-east of Valudayur and half a mile along that canal towards south-east; at four places on the way thence to Kadaperikupam; at the kilns half a mile south-west of Kadaperikupam; at Kadaperikupam; at Saidarampet; at the kilns quarter of a mile east-north-east of Saidarampet; half a mile west of Akasampati; quarter of a mile east-south-east of Akasampati; quarter of a mile south of Wattampalliam (French part of village called Sanjiverampet), and lastly in the bed of a large open tank near Royapudapakam.

The limestone is the only continuous bed of hard rock in the Pondicherry cretaceous. At the Usteri canal I estimated the total thickness to be five feet of limestone, with partings of sand. At Saidarampet a solid bed of limestone showed two feet thickness with a dip of four degrees south-east.

Most of the fossils are obtained from the overlying sands. Amongst them are some very characteristic corals (*Coryophylla arcotensis*, *Cyclolites conoidea*), *Teredo* tubes in abundance and very large gastropods (cones of one foot length), *Nautilus serpentinus* and one nautilus with a very sharp keel, apparently a new species.

The limestone dips generally towards south-east, the surface of the country coinciding with the dip slope. Above the limestone, clays and sands with nodules continue. One clay bed with layers of nodules has already been mentioned as containing some shells with light coloured phosphatic cores. In this bed remains of a turtle were found. Still higher up in the series large concretions of two feet diameter are seen in an excavation one mile north of Tirusitambalam (at the road fork). Near Tirusitambalam I noticed yellow clays with minute bivalves, and similar clays continue up the side of the Red hills ridge. These were no doubt the upper-most cretaceous deposits mentioned by Mr. H. F. Blanford, page 160, Vol. IV.

A line of section.

These six horizons represent the whole sequence of the cretaceous strata. With the exception of horizon F the exposures of the strata are very few and it would be difficult to find a continuous sequence. But there is, however, a line of section, in which four horizons are well represented and the other two at least indirectly. This is along the Tindivanam Pondicherry road. Starting at a place 12 miles from Pondicherry, we obtain a fair section along a straight road of about $4\frac{1}{2}$ miles length, along which exposures of most of the horizons are seen.

Dip of strata.

The general dip of the sequence of beds was given by Mr. H. F. Blanford as two degrees, which accords with my own observations.

Thickness.

The total thickness of the cretaceous rocks of Pondicherry may be about 900 feet.

Preliminary table of fossils.

The fossils obtained were sent to Vienna for determination and they have since been examined by Dr. F. Kossmat of the University of that city. He will describe the collection in detail, but has given the annexed preliminary list of fossils.

Preliminary List of Fossils.	Horizons.				
Caryophyllia arcotensis Forb.	...	...	...	...	F
Cyclolites conoidea Stol.	...	...	...	...	F
Hemiaster, n. sp.	...	...	D	...	...
Stigmatopygus elatus	...	C	...	...	...
Terebratula arabilis, Forb.	...	...	D	...	...
Alectryonia ungulata, Schl.	...	C	D	E	...
Exogyra ostracina, Lam.	...	...	...	E	...
Gryphaea vesicularis	...	...	...	...	F
Plicatula	...	...	D	...	...
Spondylus, n. sp.	...	...	...	...	F
Spondylus calcaratus, F.	...	...	D	...	...
Pinna cf. laticostata, Stol.	...	C	...	...	...
Modiola flagellifera, Forb.	...	C	...	...	...
Modiola polygona, Forb.	...	C	...	...	...
Macrodon Japeticum, Forb.	...	...	D	...	...
Trigonoarca sp.	...	C	...	...	...
Trigonoarca Galdrina, F.	...	C	D	E	...
Cyprina cristata, Stol.	...	...	D	...	...
Protocardium bisectum, Forb.	...	C	...	...	...
Panopaea orientalis, Forb.	B	C	...	...	...
Pholadomya caudata	B	C	D	...	...
Corimya pertusa, Stol.	...	C	...	...	...
Pharella obscura, Forb	B	C	...	...	...
Teredo aff. glomerans	...	...	...	...	F
Phasianella cf. conulata, Stol.	...	C	...	...	...
Euspira sp.	...	...	...	E	...
Euptycha larvata, Stol.	...	...	...	E	...
Nerita sp.	...	C	...	...	...
Nerita divaricata, Orb.	...	C	D	E	...
Turitella sp.	...	...	D	E	...
Cerithium, n. sp.	...	...	D	...	F

PRELIMINARY LIST OF FOSSILS.	HORIZONS.				
Nerinea, n. sp.	...	...	...	...	F
Cypraea Newboldi, F.	...	...	D	...	...
Cypraea sp.	...	...	D	E	...
Cypraea Kayei, Forb.	...	...	...	E	...
Rostellaria palliata, Forb.	...	C	...	...	...
Athleta purpuriformis, Forb.	...	C	...	...	...
Nautilus sp.	...	...	D	E	F
Nautilus aff. Bouchardianus	...	...	...	E	...
Nautilus cf. serpentinus, Blanf.	...	...	...	...	F
Nautilus sphaericus, Forb.	...	...	...	...	F
Lytoceras sp.	B	...	...	...	...
Hamites subcompressus, Forb.	...	C	...	...	...
Hamites indicus, Forb.	...	C	...	...	...
Hamites tenuisulcatus Forb.	...	C	...	...	...
Ptychoceras sypho Forb.	...	C	...	...	...
Baculites, sp.	...	C	...	...	...
Baculites vagina, Forb.	...	C	D	E	...
Desmoceras sp.	...	C	...	...	...
Pachydiscus ganesa, Forb.	...	C	...	...	...
Pachydiscus species	...	C	D	...	...

The fauna.

Dr. Kossmat intends giving a fuller description of the fossils later on, but I am authorized to state that he considers the Pondicherry cretaceous series to belong to the Ariyalur division. I may also remark here that these fossils have confirmed this conclusion, which Dr. Kossmat had already arrived at from other evidence; he had compared the original type specimens of the cepalopods of the Utatur and of the so-called Valudayur groups and had also discovered new points of agreement between the fauna of the Ariyalur group of the Trichinopoly area and the Valudayur group, and also with the cretaceous fauna of Natal. The Valudayur group will cease to be so distinguished and the horizons A, B, C, will have to be considered to be lower Ariyalur only

Some early allusions *to* Barren Island; *with a few remarks thereon, by* F. R. MALLET, F. G. S., *late Superintendent, Geological Survey of India.*

When writing the description of Barren Island that appeared in the twenty-first volume of the Survey Memoirs, I was unable to refer to any accounts of the Volcano earlier than that by Lieutenant Colebrooke, who saw it from a distance in 1787, and that by Captain Blair, who landed during a violent eruption in 1789[1]. The name 'Barren Island,' however, was not originally given by either of those observers: it had been applied before their time to the Volcano, which, by some, had also been called 'Monday' and 'High' Island. It was clear, therefore, that the island was more or less known before Blair's visit, and it seemed possible that some one or more accounts of it, by navigators who had seen, or even landed on it, might be in existence, and that perchance some allusions to its volcanic condition earlier than those mentioned above, might be on record. I have recently taken advantage of residence near London to try whether any such accounts could be found, and with this object in view, have made a somewhat laborious search at the libraries of the India Office, the British Museum, and the Public Record Office. The examination of a very large number of printed works and manuscripts has, I am sorry to say, not led to the acquisition of a corresponding amount of new information, and there can be little doubt that there still exist accounts which remain to be discovered. But the following records, however meagre, at least add something to our knowledge of the volcano.

Van Linschoten, 1595.

The earliest indication of the island being known, that I am aware of, is to be found in the original Dutch edition of Van Linschoten's[2] voyages[3]: this work contains two maps engraved in 1595, one of India and some adjoining countries, the other of the Malay Peninsula and archipelago[4]. The 'Andemaon' and adjacent islands are included in both, the configuration in one being identical with that in the other. 'Nacondaon' is placed in lat. 14° 20′. No longitudes are given, but the position is 90 miles[5] E. or E. ½ N., from the northern end of the Andamans. About 45 miles S. by E. from "Nacondaon" (Narcondam), in Lat. 13° 35′, there is a nameless island which is much nearer the true latitude of Narcondam (13° 26′) than that to which the name is attached, and it is probably a duplication of that island, through a discrepant, and more accurate, determination of its position.[6]

[1] Asiatic Researches, Vol. IV, p. 397.

[2] Erroneously printed "Linschten" in Memoirs, G. S. I., Vol. XXI, foot-notes to pages 264 and 285.

[3] "Itinerario Voyage ofte Schipvaert, Van Jan Huygen Van Linschoten naer oost ofte Portugaels Indien," etc., Amstelredam, 1596.

[4] Facsimiles of these maps (but with the Dutch titles, etc., rendered into English) are included in "John Huighen Van Linschoten, his Discours of Voyages into ye Easte and West Indies," London, 1598, a translation of the original work.

[5] Here, and elsewhere, the miles given are nautical ones.

[6] On a "Chart of the Bay of Bengal," contained in the "East India Pilot, or Oriental Navigator," and dated 1778, or nearly two centuries later than Linschoten's maps, "Narcondam of the Portuguese "| is marked in Lat. 13° 47′ and "High I. or Narcondam of the

A second small and nameless island is marked about 45 miles east of the Andamans, in Lat. 12° 25′. This is some 10 or 12 miles N. W. from the true position of Barren Island, for which, I think, there can be no reasonable doubt that it is meant, as there is no other land for which it can possibly be intended.

Linschoten makes no mention of having himself visited the Andaman Islands. In the titles of the above named maps it is stated that they were "perfectly drawne and examined with the most expert cardes of the Portingales Pilots," which suggests that the island just mentioned were inserted on Portuguese authority as the explorer who charted them thought Narcondam worthy of a name on the map. Perhaps if Barren Island had been in eruption, and thus specially attracted his attention, he would have attached one to it also.

On many charts of much later date than Linschoten's, no land near the position of Barren Island is indicated. Hence it was a new discovery to Captain H. Gough, when he sighted it in 1708.

Gough, 1708.

The log of his ship, the Stretham, is preserved at the India Office. On the 17th December of the year just mentioned, the following entry was made:—"Now at sunrise we see Land[1] from W. b. N. to N. W. b. N., at 7 o'clock ye squall being over we had an Island appearing thus" (small sketch given); "then ye other land bore from W. to N. W. by W. distance, I judge, 10 or 12 leagues. Now we have no drafts[2] that anything answer these bearings; therefore I commenced one From ye Lat. 11° which will include ye shoall,[3] to Lat. 14°, which will carry me to ye Cocos Islands; see the other side." The last sentence refers to Gough's M. S. chart,[4] on which the island, without any name, is marked in Lat. 11° 53′, and 58 miles E. S.E. from the Andaman coast. It is about 23 miles south of the true position of Barren Island, an error which is probably due to the fact that while Gough obtained his latitude on the 16th by observation, that on the 17th was by "account." There is, however, a discrepancy between the log and the chart. In the former his latitude on the 17th is given as 12° 30′, while on the chart his position at noon is marked in Lat. 12° 18′. If this difference were applied to the island, it would bring its latitude within 11 minutes of the correct one.

The island when seen was at a distance of 8 or 10 leagues to the E. S. E., and

French" 45 miles to the S. E. by E. in Lat. 13° 20′. On "a general map of the East-Indies" (1781), contained in the same Atlas, "Narcondam according to the Portuguese" is marked in Lat. 13° 45′, and "Narcondam or High Island according to the French," 60 miles to the S. by E. in Lat. 12° 50′. The French Island is certainly not intended for Barren Island, although the latter, as previously remarked, has also been known under the name of High Island. (See remarks, further on, about the "Flat Islands," and *cf.* Memoirs G. S. In Vol. XXI, foot-notes to pages 264 and 285). I have not succeeded in finding any original accounts of the Portuguese or French observations.

[1] The Andaman Coast.

[2] The obsolete term for chart.

[3] The "Flat Rock, awash" of the Admiralty chart (lat. 11° 8′). Capt. Gough puts it in 11° 10′, and on the 14th December writes :—Now as we rose from dinner we see Breakers N. N. E. of us nothing appearing above water. I suppose them 7 or 8 miles of as they broke high. We tacked. This shoall we find in our Drafts as to Latitude, but its laid not above 7 leagues off ye little Andemons and we see them not."

[4] Scale 3½ inches to 1° of latitude. A copy, on a reduced scale, is included in Dalrymple's Plans and Charts.

measures on the chart about 4 miles × 2, with the length perpendicular to the line of sight; but this was evidently a mere eye-estimate.

There is a rough free-hand sketch of the island in the log, from the point of view just mentioned, which represents it as a very high one,[1] with the culmination near the S. S. W. extremity, a nearly flat top inclining gently towards the N. N. E., and steep slopes at the ends exactly the appearance which Barren Island, at the present time, would have, if viewed from the same position,[2] except that the height, in proportion to the breadth, in the sketch,[3] is a good deal more than in nature. This is so obviously due to exaggeration, which might, perhaps, be almost expected in a rough outline evidently dashed off *currente calamo*, that it would be waste of space to raise the question whether the valcano really was much higher in 1708. Had such been the case indeed, the truncation of the ancient cone must necessarily have been far less than is implied by the sketch, and the latter would entirely fail to represent the facts.[4] There is no indication, in the sketch, of smoke[5] rising from the volcano.

Various observers.

Reference to the observations of several navigators may be found in a "Memoir of a chart of the Indian Ocean," 1787 (contained in the first volume of Darlymple's Nautical Memoirs), where at page 36 we read:—

"The Island, called *Barren Island* by Capt. Taylor and Capt. Justice, *Monday Island* by Cheyne, from old Draughts; and *Alto* by Capt. Baker and C. Alves[6] is in

Lat.	12°·20′ N. by C. Mills,	1758.
	12 22 Alves,	1760.
	12·20 Justice,	1771.
	12·20 Taylor,	1780.

Long. by Capt. Taylor's observations of Sun and Moon 93° 10′E. from Greenwich."

Cheyne, 1748.

The log of Capt. Cheyne's ship[7] (the Lapwing) shows that Cheyne passed "Monday" (Barren) Island, at the close of October 1748, and saw it from various points of the compass, but he made no nearer approach than 8 or 9 leagues. His observed latitudes on the 28th and 29th, combined with the bearings and estimated distances of the island, respectively made it in lat. 12° 6′ and 12° 16′. He remarks that "this by some is called Monday Island, but we have no account of it in the draught."

[1] The greatest elevation, as measured by Capt. Hobday in 1884, is 1,158 feet: therefore allowing for curvature and refraction, the island at a distance of 8 leagues would rise more than 700 feet above the horizon, while at 10 leagues it would still rise nearly 500.

[2] *cf.* Capt Hobday's sketch, in the corner of his map (Memoirs, Vol. XXI), taken from nearly the same bearing, but much nearer the volcano.

[3] One to five, which, under the circumstances of distance mentioned, would indicate a height of more than 2,000 feet if the sketch had been drawn accurately to scale.

[4] *cf.* Remarks, in the succeeding paper, as to the probable antiquity of the truncation.

[5] A convenient term, and quite as accurate as cinder and ash, in connection with volcanoes.

[6] "Barren Island, still smaller than Narcondam, is called likewise *Monday Island*; and by the Portuguese *Ilha Alta* (High Island)." 'The Oriental Navigator,' by J. Purdy, London, 1826, page 350. The information in this work about the Andamans is of somewhat old date and "extracted chiefly from Capt. Richie's account."

[7] India Office Records.

In the year 1758, Captain Mills, of the Drake, noticed "Land even with the water" in Lat. 11° 12', and "he says the land and (Alto, which he calls) *Arracondam*, bears of each other N. b. E. ½ E. and S. b. W. ½ W. distant 21 leagues,"[1] which makes the latitude of Alto (Barren Island) 12° 12', or within 4 minutes of the now accepted value. This quotation is of interest from the name Arracondam (presumably a corruption of Narcondam) being applied to *Barren Island*. Although I do not think Captain Mills' application of the name can be taken as proving anything, as he probably so used it through imperfect information, still the point is worthy of notice in connection with the origin of the term Narcondam alluded to in my memoir on the volcanoes.[2]

Mills, 1758.

I have not met with any record by Captain Alves or Baker. The discovery of a dangerous rock was reported by Captain Justice in 1771, which he describes in some detail[3] and at the conclusion says "Imagining I was to the westward of the Little Andaman I stood to the N. N. E.—ward in order to get its true place, but on the 2nd November, at 6 o'clock in the morning, I was surprised to see *Barren Island;* it lays by my account, not allowing the current, to be 20 miles to the westward of Barren Island[4] in the latitude of 11·07 or 11·12."[5]

Justice 1771.

The following remarks by Captain Taylor[6] of the Ship 'Ceres' are perhaps worth reproduction in full, as illustrative of the inaccuracy and uncertainty that prevailed about Barren Island until late in the last century:—

Taylor 1780.

× × × × ×

"January 12" (1780), "per medium of 13 good sights of the longitude found ourselves in 93° 36' longitude from Greenwich, which is 1° 33' W. since last sights and by the charts is nearly the longitude of the Islands, laid down in 12° and 11° 30' N. Lat. by the name of *Barren Island.* Kept a very good look out in the night and sounded as per log; next morning at daylight saw a pretty large Island bearing N.E. ½ E., 10 leagues, the ext. of the *Andamans* (just in sight) from W.N.W. to S.W. by S., 9 or 10 leagues. Till noon, that we had a good observation, could not determine whether the Island in sight was the northernmost *Barren Island* or *Narcondam;* we observed in 11° 59' N., the lat. of the northernmost *Barren Island* as laid down in the charts; the Island bearing N.E. by N. between 8

[1] Memoir of a Chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[2] Page 284.

[3] He was not, however, the original discoverer of the danger, which was seen by Gough in 1708, and alluded to by him as previously known.

[4] *i.e.* the rock is 20 miles west of the meridian of Barren Island.

[5] M. S. Bengal Public Consultations, India Office Records; and Memoir of a Chart of the Indian Ocean, 1787, (*op. cit.*), p. 36. I may mention here, incidentally, that the earliest illustration of Narcondam I have met with, is to be found on a "Chart from Negrais to the Island Carnicobar, by John Richie, 1771" (Dalrymple's Plans and Charts), as might be anticipated in respect to an extinct volcano; this sketch ("Narcondam, bearing E. by S. distant 7 miles"), shows no perceptible variation from the present outline. On this Chart Barren Island is not indicated.

[6] Dalrymple's Nautical Memoirs, Vol. II.

and 9 leagues distant which makes it come nearest the lat. of Barren Island. A day or two afterwards by a very good observation within 2 or 3 miles from the northern end of it, find its latitude to be 12° 20' northern (21 miles to the northward of its situation upon the Charts)[1] and its longitude, by several very good observations of the Sun and Moon, to be 93° 10' E. from Greenwich.

The nearest of the *Andaman* Islands we could see bearing S.W. by W. from it 18 or 20 leagues. As for the southernmost *Barren Island* we concluded that it did not exist, or if it did, that it must be very erroneously placed in the charts, for the day after we saw *Barren Island* we were set to the southward in endeavouring to pass to the eastward of it, and at noon had the Island bearing from N.b.W. to N.N.W., 12 leagues and observed in 11° 48' N., which is nearly the southernmost *Barren Island* (as laid down) notwithstanding which, saw no such Island although the weather was very clear; since which time I was informed by the Captain of a Portuguese schooner that he had seen both the Islands, the southernmost being situated much further to the westward than laid down.

"I likewise have it from good authority that Captain Sharrington of the Bahar country ship saw the rocks under its ship's bottom and sounded in 4 fathoms *Barren Island* being N.N.W. 5 or 6 leagues. In the charts there is some dangers laid down[2] to the southward of the southernmost *Barren Island*, I imagine it is meant to be placed to the southward of the northernmost, as I think it seems doubtful whether there are but one or two Islands. The Island of *Narcondam* bears N. by E. ½ E. 23 leagues distant, from *Barren Island* in lat. 13° 26' N. and Long. 93° 30' E. from Greenwich, both ascertained from very good observations. The Island *Narcondam* and *Barren Island* appear very different when seen at some distance; so that, independant of their latitudes, with a simple sketch of each Island a man could be at no loss readily to know the one Island from the other. *Narcondam* makes like a sugar loaf, quite flat at the top, and may be seen at least 18 leagues from the mast head, for we saw it 13 or 14 leagues from the poop pretty high out of water, the weather rather hazy; this distance may be depended upon as its calculated from the bearings and differences of latitude.

"*Barren Island* appears much longer, but not quite so high; the watermost ext, is the highest, and makes with a peak, descending to a low point to the eastward, although when you come near it, it seems of an equal height, with a peak at each end; it may be seen at least 15 or 16 leagues, for it was high out of the water when we saw it bearing N. by W. 12 or 13 leagues distant per calculation."

One Island, or two?

In explanation of Captain Taylor's surmise, whether one Barren Island, or two, existed, I may say that in various atlases of the eighteenth century[3] two small islands are marked, one nearly due north of the other, on a meridian some 50 miles east of (what appears to represent)

[1] *Cf.* Gough's observations. F. R. M.

[2] That reported by Gough and Justice? F. R. M.

[3] *e. g.* "Le Neptune Oriental on Routier général des Côtes des Indes Orientales," Paris, 1745 (*Isles Rases*). "Carte de L' Inde par le Sr. D'Anville, dated 1752, contained in the same author's "Géographie Ancienne Abrégée," 1769 (*Isles Rases*). "A New Directory for the East Indies" (based on Le Neptune), 6th edition, London, 1767 (Barren Islands). "The East India Pilot or Oriental Navigator," 2 charts dated respectively 1778 (Flat Islands and Barren Islands—both names given) and 1781, Flat Islands.

the South Andaman. The latitude of one varies from 11° 21′ to 11° 30′; that of the other from 11° 59′ to 12° 8′. In the French Atlases these are called the '*Iles Rases,*' while in some of the English they are called the 'Barren Islands' and in others the 'Flat Island.' However, one or two of these names came into use (possibly through some mistranslation from one language into another), the northern *Isle Rase*, as charted, agrees very fairly in position with Barren Island, and cannot be intended for anything else. What the southern *Isle Rase* was intended for I do not know. It was not meant for the rock east of Duncan's passage,[1] for in some Atlases, (*e.g.*, Le Neptune Oriental), the latter is marked *in addition to* the *Isles Rases*, in latitude 10° 55′ or 11° 0′.

Perhaps the most likely solution is that (like Narcondam, as previously mentioned) Barren Island was duplicated on the charts, through discrepant determinations of its position. But it is at least a possibility that, like Graham's Island, in the Mediterranean, the southern Isle may have been an ephemeral one, due to a volcanic eruption, chiefly of fragmentary ejecta. It is conceivable that, after it had been washed away by the sea, the last visible remnants were the rocks reported by Captain Sharrington, 5 or 6 leagues S. S. E. of Barren Island, and that even these subsequently disappeared, thus explaining Horsburgh's remark that Sharrington's account "is rendered doubtful, for no signs of a shoal-bank in the situation described have been discoverd for many years."[2]

Another possibility is that the temporary Island, and Sharrington's rocks, were S. S. W. of Barren Island (the S. S. E bearing given by Taylor being due to a not uncommon kind of clerical error). This would place them in the line joining Flat Rock, Barren Island, and Narcondam, and on the suppositional submarine ridge of Dr. Prain,[3] and would account, in another way to that suggested above, for the rocks not being re-discovered to the S. S. E., as well as for the statement of the Portuguese Captain. It would be useless, however, to pursue this speculation reared on such a slender basis.

Blair, 1789.

I have made unsuccessful attempts, at the libraries mentioned, to discover the original of Captain Blair's report on the Andamans, part of which, relating to Barren Island, is quoted by Lieutenant Colebrooke in the Asiatic Researches. The following letter,[4] however, dated 19th April 1789, serves to supplement the above: "To the Right Hon'ble Charles Earl Cornwallis, K. G., Governor General, etc., in Council :—

My Lord * * * * After examining Diligent Strait and the archipelago, I proceeded to Barren Island and found the volcano in a violent state of eruption, throwing out showers of red hot stones and immense volumes of smoke. There were two or three eruptions while I was close to the foot of the cone; several of the stones rolled down and bounded a good way past the foot of it. After a diligent search I could find nothing of sulphur or anything that answered the description of lava. * * * I have, &c. "Archibald Blair."

[1] The 'Flat Rock awash' of the Admiralty chart; that reported by Captain Justice.

[2] India Directory, 3rd edition, 1827, Vol. II, p. 37.

[3] See abstract of his memoir in the following bibliography.

[4] Bengal Political and Secret Consultations. Dated Fort William, the 21st August, 1789. India Office Records. The portions of the letter omitted relate to the Andaman Islands.

The preceding account is, in most respects, very similar to that in the report alluded to, and the chief interest lies in the final sentence. I have argued, on other grounds,[1] that the lava streams which now extend from the central cone westward towards the sea were emitted after Blair's visit; but his own statement, that after diligent search he could find nothing resembling lava, puts the question beyond discussion. It is scarcely conceivable that any one, however inexperienced in volcanic geology, could fail to recognize the true character of such typical streams at the first glance.[2] There are, however, still further proofs that the lava was emitted after Blair's time. From the points of issue the streams flowed down the slope of the cone, and their heads now constitute a portion of its surface, so that there have been no accretions to the cone since the occurrence in question. But it is shown, in the succeeding paragraphs, that the cone has greatly increased in bulk since 1789, and any lava emitted then, or previously, and solidified on its flanks, would now be deeply buried beneath the later products of eruption. I have previously stated,[3] that no fragmentary ejecta (scoriæ, &c.) have ever fallen, direct from the crater, on to the surface of the lava, which must, therefore, have been emitted after the last eruption of such material. In other words, the lava must be the latest volcanic product, and cannot, apparently, have been emitted earlier than 1804, the date of the last outburst of which we have any record. We have no reason to suppose that the different streams were emitted at considerable intervals, and the existence of the hot spring in 1832 shows that the southern stream, at least, had been poured forth before that date.[4] That Blair found no sulphur is very natural. The superficial deposits are entirely confined to the newer cone,[5] which was inaccessible to him, owing to the eruption. Even if he could have ascended it, he would have found none. The present deposits have been formed since the last eruption of scoriae, and therefore long after his visit, while the outburst he witnessed must have destroyed, or buried, any previously visible.

Captain Blair's landing on the island still remains the first, of which we have any record.

It is worthy of mention in connection with Blair's visit, that Test's "view of the volcano on Barren Island, bearing east, about one mile off"[6] taken the day before Blair landed, gives the means of arriving at an approximation to the height of the newer cone at that time. The sketch represents the summit of the cone as rising very slightly above the sky line of the old crater rim behind it, and a careful comparison of corresponding points in the sketch, and in Hobday's map of 1884, shows that the artist, the summit of the cone, and the eminence on the old crater rim which Hobday marked as 1060 feet, in height, were in a line; and likewise shows that the eminence in question was concealed, and only just concealed, by the summit of the

[1] Mem. G. S. I., Vol. XXI, p. 271.

[2] There was of course lava in abundance visible to Capt. Blair, at a distance, where it outcrops, interbedded with scoriae, on the scarped walls of the ancient crater. But its petrological character in such position would be far from self-evident to a non-geologist.

[3] Mem. G. S. I., Vol. XXI, p. 271.

[4] *Ibid* p. 274.

[5] There may possibly exist buried deposits amongst the rocks of both the ancient and the newer cone.

[6] A water colour sketch measuring 16½ inches × 6: British Museum library, Press mark K. 116, 31, *Vide* Mem. G. S. I. Vol. XXI, p. 262, the illustration accompanying this paper is a photographic reproduction on the scale of one-half.

cone[1]: in other words, the eminence and the cone subtended almost exactly the same angle, their respective distances from the point of view, and the height of the eminence,[2] being obtained from the map, give the height of the cone as exactly 800 feet, assuming the two angles involved to be identical, and that Test estimated his distance from the shore correctly. I do not think any probable difference in the angles would make a difference of more than 20 or 30 feet in the height, while an error of a quarter of a mile in the estimated distance, one way or the other, would make a difference of about 30ft. The errors due to these two sources if they exist, may partially, or entirely, neutralize each other; but even if they are both of the same sign, the total error is probably well under 100 ft., and is almost certainly not over this amount. While, therefore, it may be taken as almost beyond question, that the height of the cone was between 700 and 900 ft., it is much more likely that it was between 750 and 850 than outside these limits, and the most probable altitude is about 800[3].

Lieutenant Wales' sketch, as reproduced in the Asiatic Researches (Vol. IV) is on a smaller scale than Test's, and shows marks of less careful elaboration; but the height calculated from it agrees very fairly with the above, giving the most probable elevation as between 800 and 830 ft., the lower figures being the more likely.

Corroborative evidence of a considerable increase in the size of the cone is afforded by a large protuberance, represented in Test's sketch on the lower part of the north-western slope. This was quite obliterated in 1884, owing, doubtless, to its having been buried beneath the ejecta that have been emitted since Test used his brush.

Supposing the true height to have been 800 ft., the cone, which is now 1015 must have just doubled in bulk between the time of Blair's visit and 1857, since which date we know that there has not been any eruption, a suggestive conclusion in regard to the period of time during which the entire pile may have been heaped up.[4]

Test, like others,[5] over-estimated the slope of the newer cone, where, as is mostly the case, the sides are composed of fragmentary ejecta, the declivity is almost perfectly uniform, at an angle of about 32 degrees, except near the base, where the inclination gradually diminishes in a graceful curve.[6]

[1] That is to say if the cone were away, the sky-line of the crater rim would be seen to rise towards, and culminate in the eminence. As the sky line at each side is but slightly lower than the summit of the cone (in the sketch), the eminence must be, as nearly as possible, equally high.

[2] Test's sketch gives no reason to suppose that the height of the eminence is different now to what it was in 1789, although it is perhaps a few feet more, owing to accumulations of scoriae due to the eruptions since then. Any alteration due to movement of the crater walls (had such occurred) would probably be in the direction of subsidence, and would tend to reduce the calculated height of the newer cone.

[3] According to Blair's account, as quoted by Colebrooke, the elevation was "1,800 feet nearly"; a manifest clerical error. Were the figures he actually gave 800?

[4] *Cf.* Mem. G. S. I., Vol. XXI, p. 265.

[5] As pointed out by Dr. Ball (Records, G. S. I., Vol. VI, p. 82).

[6] See illustration in Mem. G. S. I., Vol. XXI, p. 251.

Hall, 1795.

The following extract from the log of the Ship 'Worcester,'[1] commanded by Captain Hall, adds one more to the recorded eruptions towards the close of the last century:—

"Sunday, 20th December, 1795. At 10 A.M. the Commodore made the signal for seeing the land. Saw a long Island higher at the westward end sloping gently to the eastward N. W. ½ W. 14 or 15 leagues off deck. At noon it bore from N. W. to N. W. ½ W. take it for Barren or Monday Island. In the centre a smoke arises and has the appearance of a volcano. Its Lat. by the bearings is 12° 22' N. and Long. by my chron. No. 1, 93° 54' E. Greenwich × × × ×.

"Monday, 21st × × × ×. At 6 A.M. it bore S. ½ W. about 10 leagues and Narcondam (both from the deck) N. N. E. ¾ E. about 12 leagues. It was astonishing the repeated columns of black smoke which were sent up. There appeared no hill (as the whole Island is nearly a plain surface gently sloping to the eastward as mentioned in yesterday's log) but the smoke was from the other side of the ridge or on the eastern side."

Any one unacquainted with the true topography of the Island, and viewing it from a distance of several leagues, might easily suppose it to have a nearly plain surface, or to form a ridge. Captain Hall's remark that the Island is "higher at the westward end sloping gently to the eastward" agrees with Captain Taylor's that "the westernmost extremity is the highest, and makes with a peak descending to a low point to the eastward." But this appearance is evidently a deceptive one, as Captain Hobday's map shows that the volcano is highest towards the south-east, and we have evidence, in Test's sketch of the Island in 1789,[2] that, as far as the ancient cone is concerned, the outlines then were practically identical with the present ones.

Cason, 1804.

The volcano was again in eruption at the end of January 1804, when H. M. S. "Caroline" passed the Island. The log[3] contains the following entry on the 31st—"Several eruptions of fire from the volcano on Barren Island during the night." This outburst (as pointed out by Dr. V. Ball[4]) is also mentioned, by one of the officers, in an "account of a voyage to India and China, etc., in H. M. S. "Caroline."[5] His remarks are given in the following table.

Probable condition of volcano in 18th century.

Not one of the observers before Colebrooke (1787) record any appearance of smoke rising from the Island, or make any remark indicative of their being aware of its volcanic nature, from which it may not unreasonably be assumed that, when they saw the volcano, it was quiescent or at most giving off a little steam.[6] It seems difficult to imagine that while the bearings, etc., of the Island were duly recorded in the log, an eruption, if witnessed, should be absolutely ignored, and we may, perhaps, further surmise that the volcano was in the same condition when seen by the unknown

[1] India Office Records.

[2] *Vide* accompanying reproduction and Mem. G. S. I., Vol. XXI, p. 262.

[3] Public Record Office.

[4] Geological Magazine, 1888, p. 404.

[5] Phillip's Voyages and Travels, Vol. V.

[6] Colebrooke saw smoke when he was 7 leagues off the Island, and Hall (1795) when 10 leagues, or more. Such indeed would be easily visible when the Island itself was below the horizon.

observers who first applied the names 'Monday' and 'Barren' Island; at dates we are unacquainted with, but which seem not improbably to lie between 1708, when Stretham charted the Island as an anonymous one, and 1748, before which time both names appear to have been in use.[1] Had the volcano been in eruption when the observers in question saw it, it does not seem unlikely that they would have given names suggested by the remarkable phenomenon of which they were spectators.[2]

Assuming, however, that the volcano was quiescent at the dates previously given, it would still be unsafe to argue very confidently as to its general condition in the eighteenth century, as, during the intervals of which nothing is known, many eruptions may have occurred for ought we can assert to the contrary. But, at the same time, the fact that on every one of the six dates included in the following records, between 1787 and 1804, the volcano was very active, and mostly in eruption, while on each of the (three or) four dates between 1748 and 1780 it appears to have been quiescent, can hardly be attributed entirely to chance. Hence it can scarcely be doubted that several outbursts during the two decades following 1785, have passed unnoticed, while we shall, perhaps, not greatly err if we regard the preceding four decades as a period of at least comparative, and possibly total, tranquillity. There is also, as we have seen, some very slight ground for surmising that this tranquillity may have extended back to the early part of the century. Of antecedent ages we know nothing from direct observation unless the suggestion thrown out in connection with Linschoten's map may be taken as one very faint hint.

Tabular abstract.

In conclusion, it may be convenient to add a revised edition of the tabular abstracts given in my memoir on the volcano,[3] incorporating the preceding records, and also the observations that have been made since 1884.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
1595 .	The Island appears to have been known at this time, but there is no indication of its volcanic nature having been recognised.	......	Maps in Van Linschoten's itinerario.
7th Dec. 1708.	Dormant	......	Captain Gough; log of ship "Stretham."
28th & 29th Oct. 1748 .	Dormant	......	Captain Cheyne; log of ship "Lapwing."
1758 .	Dormant?	......	Captain Mills, of ship "Drake." "Memoir of a chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[1] *Cf.* Notice of Cheyne's observations, and foot-note mentioning "Le Neptune Oriental" etc.

[2] *Cf.*, however, foot-note in the next paper, on the possible origin of the name 'Barren.'

[3] Mem. G. S. I., Vol. XXI, p. 272 and 275.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
2nd Nov. 1771 .	Dormant	......	Captain Justice, of ship 'Union' M. S. Bengal Public consultations, and Memoir of a chart of the Indian Ocean (op. cit.), p. 36.
13th & 15th Jan. 1780 .	Dormant	......	Captain Taylor, of ship "Ceres," Dalrymple's Nautical Memoirs, Vol. II.
12th May 1787 .	"Column of smoke ascending from the summit" was seen from a distance of 7 leagues. No nearer approach to the Island was made.	......	Lieutenant Colebroke, Asiatic Researches, Vol. IV. p. 397.
24th March, 1789.	"The volcano was in a violent state of eruption, bursting out immense volumes of smoke, and frequently showers of red hot stones. Some were of a size to weigh three or four tons, and had been thrown some hundred yards past the foot of the cone. There were two or three eruptions, while we were close to it; several of the red hot stones rolled down the sides of the cone, and bounded a considerable way beyond us." The newer cone was probably about 800ft. high.	No mention of the spring. Blair was the first who landed on the island, as far as is known.	Capt. Blair, quoted by Colebrooke; *loc. cit.* Letter from Capt. Blair, dated 19th April, 1789. Test's sketch of 23rd March, 1789.
1791 .	"A quantity of very white smoke close to the crater."	......	India Directory, by J. Horsburgh, 3rd edit. (1827), Vol. II, p. 37.
20th and 21st Dec., 1795.	On 20th smoke observed: on 21st, "It was astonishing the repeated columns of black smoke which were sent up."	......	Capt. Hall; log of ship "Worcester."
November, 1803.	"Exploded regularly every 10 minutes, projecting each time a column of black smoke perpendicularly to a great height; and in the night, a fire of considerable size continued to burn on the east side of the crater."	......	Horsburgh; *loc. cit.*
29th—31st Jan., 1804.	29th. Volcano "was burning very fiercely, the eruptions taking place every eight or ten minutes, with a hollow rumbling noise. * * * We passed within a mile of it, and as the winds were trifling we observed the eruptions for three days and nights successively." 31st. Several eruptions of fire during the night. The recent lava streams appear to have been emitted not earlier than this date.	......	Officer of H. M. S. "Caroline"; Phillip's Voyages and Travels, Vol. V. Log of the "Caroline."

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
March, 1832 .	"Large volumes of thin white smoke kept continually issuing" from the summit. The southern lava stream was emitted before this date, as evidenced by the existence of the hot spring. Probably the other recent streams had also been poured forth.	"On approaching to within a hundred yards of the shore, we were suddenly assailed by hot puffs of wind, and on dipping our fingers into the water, were surprised to find it as hot almost as if it had been boiling. The stones on shore, and the rocks exposed by the ebbing of the tide, were smoking and hissing, and the water was bubbling all round them."	Commander of a ship; Journal, Asiatic Society of Bengal, Vol. I, p. 129.
April, 1843 .	From the summit of the cone "a clear and full stream of transparent vapour issued, so transparent that it was not perceptible from the sea."	......	Captain Miller; Calcutta Journal of Natural History, Vol. III, p. 423.
1852 .	Very active. . . .	......	"Bombay Times," July, 1852.
18th Dec., 1857.	"Some smoke was seen occasionally to issue from the slope of the cone" a little way below the summit. The date of the last eruption is unknown, but the unchanged condition of the crater shows that there was none between December 1857 and April 1891.	Temperature "too high to be borne by the hand, the mercury in the only thermometer in our possession rising immediately to 140°—its limit."	Dr. Playfair; Selec. Rec. Govt. of India (Home Department), No. XXV, p. 123. Mem. G. S. I, Vol. XXI, p. 268. Dr. Prain; see below.
Ibid. .	......	"A natural boiling spring."	Dr. Mouat; Researches amongst the Andaman Islanders.
19th March, 1858	"Clouds of hot watery vapour," with a sulphurous smell, issued from cracks near the summit, on the northern and southern edges of the crater. The recent lava streams were (superficially) "cold."	"The water, where escaping from the rock, must have been nearly at the boiling point."	Dr. Liebig; Zeitschrift der Deutsch Geol. Gesellschaft, Vol. X, p. 299. Selec. Rec. Govt. of India, No. XXV. p. 126. Also in Jour. As. Soc. Bengal, Vol. XXIX, p. 1; and in Mouat's Researches.
1862 .	Sulphurous vapours issuing along the edge of the crater.	"Scalding hot" . .	Rev. C. Parish; Proceedings, Roy. Geog. Soc., Vol. VI, p. 217.
19th April 1866	A whitish vapour was evolved from several deep fissures near the summit.	158° to 163° F. . . .	Andaman Committee; Proceedings, As. Soc. Bengal, Oct. 1866, p. 215.
March 1873 .	From the highest point on the northern edge of the crater a thin column of white vapour, and sulphurous fumes were slowly poured forth.	130	Prof. V. Ball; Records G. S. I., Vol. VI, p. 88.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
Feb. 1884 .	Superheated steam, with sulphurous vapour issued rather copiously from the solfatara on the north side of the crater, the column, as it rose into the air, being visible from the landing-place, or even some distance out at sea. Steam, in smaller quantity, issued from some other spots also.	106° to 116° . . .	F. R. Mallet; Mem. G. S. I., Vol. XXI, p. 273, 274.
28th April 1886 .	"From the ship the thin column of steam (from the central cone) could be barely seen at 3 miles distance."	110°	Capt. Carpenter, R. N., H. M. I. M.S. 'Investigator'; Records, G. S. I., Vol. XX, p. 48 Mr. Daley, of Investigator; Ex. Cit.
April 1891 .	Some steam issued from the crater but considerably less than in 1886; it was not visible from the sea, or even from the landing-place. New crusts of sulphur, from ½ to 2½ inches thick, had been formed at the solfataras since February 1884.	102° to 106°. . . .	Dr. Prain; Proceedings, As. Soc., Bengal, May, 1891, p. 84.
1894 .	"The Volcano is apparently entering on a period of renewed activity." This somewhat vague statement does not seem to have been corroborated.	......	Port Blair correspondent of the Allahabad 'Pioneer'; quoted in 'Nature', 7th June 1894, p. 131.

Bibliography *of* Barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks by* F. R. MALLET, F.G.S., *late Superintendent, Geological Survey of India.*

The Bibliography of the Islands up to 1884 may be gathered from Dr. V. Ball's paper in an earlier volume of the records,[1] from my report of 1884, and from the preceding pages. The following papers have appeared during the last ten years, but I am not prepared to say that the list is complete, as there may be other references to the Islands which have escaped my notice.

1. "Volcano of Barren Island in the Bay of Bengal": American Journal of Science, Vol. XXXI (1886), p. 394. A critical notice of my Memoir, by Professor J. D. Dana.[2]

[1] Vol. VI (1873), p. 81. Republished in the Geological Magazine 1879, p. 16.
[2] It is, perhaps, worth mentioning here, that the statement, alluded to by Prof. Dana,

The writer discusses the way in which the upper part of the cone of a volcano is destroyed, and a great crater, like the ancient one of Barren Island, produced. He holds that, during a paroxysmal eruption, the portion of the cone in question is not blown away peacemeal, but that the walls of the crater are undermined by the melted lava, and sink down in consequence into the abyss beneath. "Finally in the catastrophic eruption when the force from the rising vapours and from other conditions becomes greater than the mountain can withstand—a point often abruptly reached—the sides break and one or more fissures let out the liquid lavas. However explosive the action, the solid rock of the summit of the cone, while it may be more or less removed by the forces engaged, instead of being projected over the outer slopes, sinks down into the abyss so made. Thus a volcanic cone under the most formidable of explosive eruptions may lose its head, but if so, it is by swallowing it, or simply by a collapse. The same is the process in quiet Kilauea, the solid lavas of the borders of the fiery region sink because the discharge of the liquid rock makes a void beneath them."

A subsidence of the lava in Kilauea, and concomitant collapse of the crater walls into the fiery lake, which took place last July, was observed by Mr. L. A. Thurston, apparently the first actual eye-witness of such an occurrence. His graphic account[1] is in complete accordance with Professor Dana's view. But Kilauea is a volcano of an unusual type, and widely different from Vesuvius or Barren Island. However large a share engulphment may have in producing great craters in volcanoes of the latter type, that it is the sole agent and that ejection of the material of the crater wall, in a more or less communicated state (produced mechanically, or by fusion), never plays a prominent part in the affair, is an opinion widely at variance with that held by most volcanologists.

2. "On soundings recently taken off Barren Island and Narcondam by Commander A. Carpenter, R.N., H.M.I.M.S., 'Investigator,' the officer in charge of the Marine Survey of India." By F. R. Mallet. Records, Geological Survey of India, Vol. XX of 1887, p. 46.

The results of soundings, taken in May 1886, are given with some remarks thereon. The depths measured within four miles of Barren Island range up to 855 fathoms, aud those within a league of Narcondam up to 652. Sections of the islands are appended, based on Captain Carpenter's soundings and Captain Hobday's maps.

3. "The volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, M.A., F.R.S.. F.G.S, Geological Magazine, 1888, p. 404.

Mainly a notice of the chief results of the survey by Captain Hobday and myself in 1884, with some remarks thereon. Refers to the eruption of January 1804, seen by an officer of H. M. S. 'Caroline' (*vide* preceding paper.)

4. "The Andamans and Andamanese." By Colonel T. Cadell, V. C., Scottish Geographical Magazine, February 1889, p. 56.

Includes a brief account of Barren Island, written partly from personal observation, partly from previous descriptions.

that the cone "has been entirely built up during the last 1800 years," is not merely in connection with Barren Island, but a quotation from Professor Judds' 'Volcanoes,' in reference to Vesuvius.

[1] American Journal of Science, Vol. XLVIII (1894), p. 338.

5. "On the present condition of Barren Island." By D. Prain, M.B., Proceedings, Asiatic Society of Bengal, May, 1891, p. 84.

Gives some of the geological results of a visit in April 1891—An abstract of these is included in the preceding table.

6. "Remarks on the Fauna of Narcondam and Barren Island." By D. Prain, M. B., Proceedings, Asiatic Society of Bengal, April, 1892, p. 109.

The paper is almost entirely geological, but, at the end, contains some remarks on the relation between the geology and biology. The author recognises that the islands are, and always have been, oceanic. "The present physical conditions in Narcondam appear, moreover, to be very ancient; there is no trace of a crater at the top of its peak which rises 2,330 feet above the level of the Andaman Sea, and the whole island is clad with a dense jungle much richer in species than the forest on Barren Island is. But though the present biological features of Barren Island are of a much more modern aspect, it is not necessary to consider that island as really less ancient than Narcondam. The topography of its outer cone, combined with the historical fact of recent activity on the part of the volcano, points to the possibility of some catastrophe similar to that which devastated Krakatau, having once happened in Barren Island, and if this has been the case it would follow that the island must have required, even if previously covered with vegetation, to be stocked *de novo* with vegetable and animal life. Still, granting that the present fauna and flora of Barren Island are of more recent introduction than those of Narcondam, the fact remains that we must look upon every species present, even in the island with the older biological features, as an immigrant one."

The only catastrophic outburst of which evidence still remains, and that, I presume, referred to by Dr. Prain is the one which probably effected the truncation of the ancient cone, and originated the crater now over a mile in diameter. From a biological point of view, as well as from a geological one, therefore, the period at which this change took place is of some interest. It is impossible to form any definite estimate of the time involved, but there is reason to believe that the event occurred at a very remote epoch. The deep gorges which score the external slopes of the volcano, point to long-continued denudation, which shows no apparent signs of having been interfered with by lava flows from the ancient cone. But still more suggestive is the gorge which debouches into the crater S. S. E. from the hot spring, unless, as is conceivable, this ravine, drained into a great east and west "barranco," which may possibly have existed prior to the origination of the present amphitheatre, the ravine must, apparently, have been excavated since the amphitheatre was formed. That is to say, since the event in question, some hundreds of feet of alternating scoriæ and lava beds have been cut through near the mouth of the gorge, where it is deepest. The stream, too, which has done the work, owing to its small size, and the porous nature of the rocks, is under the disadvantage of flowing only in the rainy season, and perhaps not constantly even then.[1]

The time indicated above is so immense, compared to that during which the

[1] The water, for some distance seaward from the breach, appears to have been somewhat reduced in depth, owing, doubtless, to the material swept into the sea from the gorge just mentioned, and from the amphitheatre generally, combined with the submarine portion of the recent lava (cf. sections in Vol. XX, p. 48.)

materials of the present cone may have been piled up,[1] as to suggest that the paroxysmal eruption, supposed to have truncated the ancient cone, was perhaps followed by a long interval of quiescence, before the building up of a newer cone was begun, and several such may have arisen, and been destroyed, before the present one was reared. In comparison with the antiquity of the older cone, the existence of the present one may date from almost yesterday. Or, to put it differently, while the duration of the one must be measured by geological time, it is possible for the other to have originated during an even historically recent period.[2]

Granting that life was extinguished by the catastrophe just alluded to, as suggested by Dr. Prain, the question may be raised whether the present fauna and flora date from that epoch, or from a still later destruction due to some overwhelming shower of ejecta. I am not competent to express any opinion as to the time required to re-stock the island : but looking simply to the probable intensity of the eruptions in comparatively recent times, *i.e.*, since the present cone was commenced. I see no cogent ground for regarding a total destruction of the island life as very probable. There is no reason for assuming that the earlier outbursts from the present cone were on an essentially grander scale than the later ones; and I have shown in the preceding paper that a large fraction, perhaps half the bulk, of the cone[3] has been added by the eruptions that have occurred since 1789. But Test's sketch shows that the exterior slopes of the island were well-wooded at that date, and that the arboreal vegetation was not subsequently destroyed may be inferred from Capt. Miller's describing the outer slopes as well-wooded in 1843, and from the fact that no remains of lifeless forest have ever been noticed.[4] At the same time it can scarcely be doubted that considerable damage has been done to the vegetation, perhaps on many occasions. But such damage would be much more severe in the amphitheatre than on the external declivities.[5]

7. "Note on the occurrence of quartz in an Indian basic volcanic rock." By T. H. Holland, A. R. C. S., Bulletin of the Microscopical Society of Calcutta, Vol. II, No. 6 (1893), p. 3.

The rock in question is from Narcondam, and described by the author as a basaltic andesite, the quartz being regarded as of volcanic, not extraneous origin.

[1] Cf. remarks in preceding paper in connection with Blain's visit, and Mem. G. S. I., Vol. XXI, p. 265.

[2] If we may regard the relative bulks of the two cones as giving some sort of rude illustration of the orders of magnitude of the two periods involved, we find that while the newer cone is about 1,000 ft. in altitude, the ancient one was probably once 8,000 or 10,000 from the sea floor (Vol. XX, p. 46), requiring, perhaps, 500 or 1,000 times as much material.

[3] That is to say, the cone above sea-level, and not including the mass of material which was doubtless required to fill up the ancient crater to that level.

[4] *Cf.* Memoirs, G. S. I., Vol. XXI, p. 262.

[5] If the view expressed in the above paragraph be correct, the island can scarcely have acquired its name from any striking barrenness of the now well-wooded outer slopes. Although I believe the name was most probably given on account of the barrenness of the newer cone, and parts of the amphitheatre, it has occurred to me, as a possibility, that, as the word Narcondam is of eastern origin, so 'Barren' may be an English corruption of some name applied by the Asiatic sailors of the region in question. The Hindustani *barna*, to burn, *barat*, burning, and *barkm jon*, a volcano, for instance, are somewhat suggestive. Some reference to the island may yet be discovered which will elucidate the origin of the name.

8. "On the Volcanoes and Hot Springs of India, and the Folklore connected therewith." By V. Ball, C.B., LL.D., F.R.S. Proceedings of the Royal Irish Academy, 1893, p. 151.

Refers, *inter alia,* to Barren Island and Narcondam.

9. "The Volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, C.B., LL.D., F.R.S., Geological Magazine, 1893, p. 289.

Descriptive of a model of Barren Island, constructed under the author's superintendence, and based chiefly on the data supplied by Capt. Hobday's map. A bird's eye photographic view of the model is given, in which the sea surrounding the island is also represented. The paper concludes with some notes on the fauna of the islands.

10. "On the flora of Narcondam and Barren Island." By D. Prain, M.B. Journal of the Asiatic Society of Bengal, Vol. LXII (1893), Part II, p. 39.

A memoir divided into three sections. The first, or 'Introductory sketch,' commences with some remarks on the hydrography of the Bay of Bengal (in its wider sense), for the portion of which, enclosed by the Andaman and Nicobar Islands, Alcock's name of 'Andaman Sea' is adopted. Carpenter's soundings round the two volcanoes[1] are reproduced, with some additions: the configuration of each island is described, and a summary account of its vegetation given,[2] the soundings round flat rock[3] are added, which the author very plausibly suggests is probably of Volcanic origin. The bathymetry of the Andaman Sea is reviewed, and the question of the northern prolongation of the line of volcanoes through the Sunda Islands, Java, Sumatra, Barren Island, and Narcondam is discussed. This the author, following Dr. W. T. Blanford, considers, is to be found in the extinct volcano of Puppa, in Upper Burma, and that near Momein, in Yunnan, which, as he remarks, lie in common with the volcanoes of the Andaman Sea, to the eastward of, and rudely parallel to, the line of elevation represented by the Andaman Islands and the Arrakan Yoma. Evidence is likewise adduced to show that Flat Rock, Barren Island, and Narcondam are not isolated peaks rising from the sea-floor, but are situated along a submarine ridge.

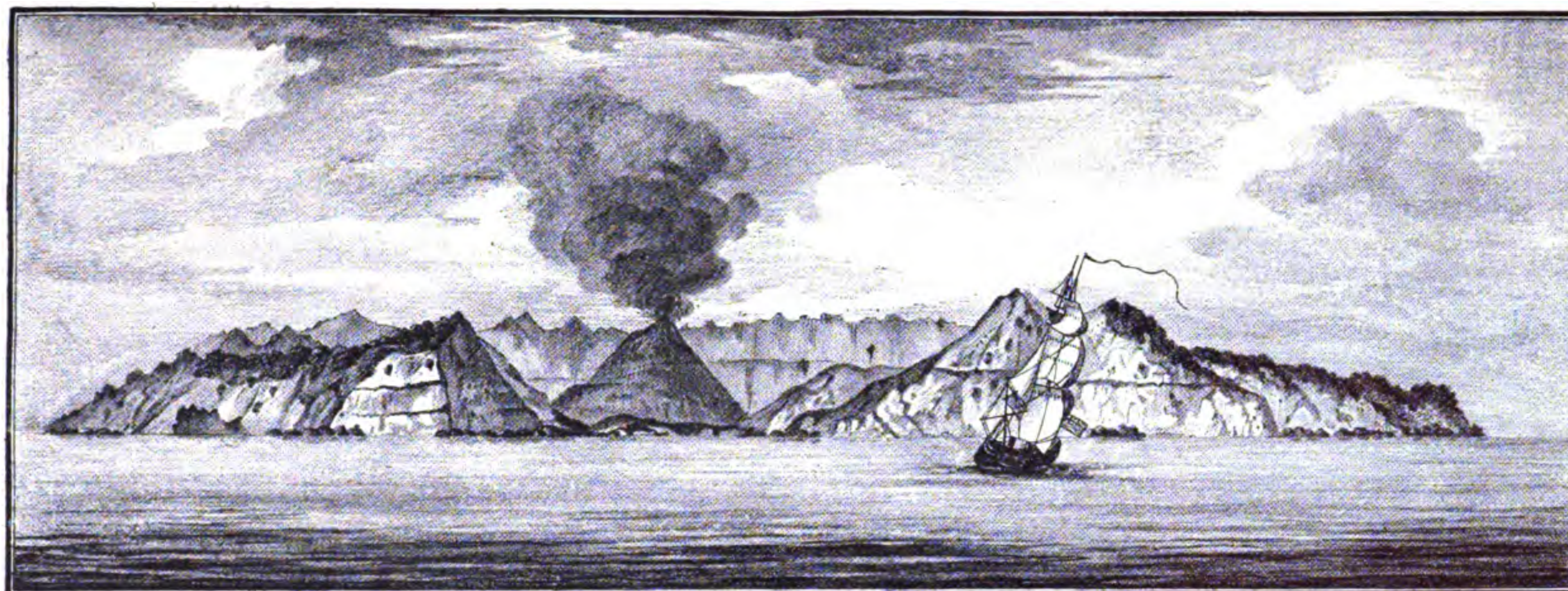
The second portion of the Memoir is an annotated list of the plants found on the islands, and the third discusses the "Nature and origin of the Flora." 174 species were discovered, of which 138 occur on Narcondam and 88 on Barren Island, only 52 being common to both volcanoes. In conclusion the probable mode of introduction—by the sea, by winds, by birds, or by man—is taken into consideration. Appended are two bathymetric charts of the area surrounding the Andaman Islands.

An abstract of the Memoir was given in the Geographical Journal for March 1894, p. 234.

[1] Records, G. S. I., Vol XX, p. 46,

[2] With reference to the foot-notes in Dr. Prain's Memoir, at pages 45, 49, 56, and 77, in connection with the occurrence of cocoanut trees on the islands, I may say that Mr. Wight, and Officer of the I. M. S. 'Celerity,' and I, landed at Coco Bay in Narcondam, and saw the trees in question there. We found a large log of teak, with hewn ends, on the beach, which may be presumed to have drifted from the mouth of some Burman river; a suggestive fact with reference to the origin of the cocoanuts from which the trees have sprung, and of other species of plants also. We, and several other members of the expedition, also landed at Anchorage Bay, in Barren Island, the surf at the time being comparatively slight.

[3] The rock east of Duncan's passage, alluded to more than once in the preceding paper.



A VIEW of the VOLCANO on BARREN ISLAND, Bearing East, about one Mile off. Taken on Board the Hon.ble Company's Snow Viper, March 23.d 1789.

ERRATA.

RECORDS, GEOLOGICAL SURVEY OF INDIA, Vol. XXVIII, part 1, pages 22—38.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1895. May

On the importance of the Cretaceous Rocks *of* Southern India *in estimating the geographical conditions during* later cretaceous times[1]; by FRANZ KOSSMAT.

OUR knowledge of the extra-European cretaceous rocks, more especially those of the Indo-Pacific area, has, in the course of the last few years, made enormous strides, and we shall soon be in a position to form a clear conception of the zoological and geographical conditions of that period. The cretaceous rocks of Southern India, which formerly, in spite of their great wealth of fossils, were accorded little more than the importance of a mere local development, are now coming more and more to the front, since the elements of their fauna have been discovered in a great series of cretaceous beds, while Neumayr [2] in his "Erdgeschichte" selects them as the type of the Pacific cretaceous area.

Nevertheless, since the completion of Stoliczka's [3] great monograph on the cretaceous Fauna of Southern India, neither our palæontological nor yet our stratigraphical knowledge of this important area has been appreciably extended, although of late years, the urgent necessity of revision—more especially as regards the cephalopods—has repeatedly asserted itself. Opportunity for such research is now offered by the new collection made in the Trichinopoly district during the winter of 1892-93, and part of the summer of 1893, by Dr. H. Warth, of the Geological Survey of India, and sent by him to Prof. Waagen, at Vienna, who has entrusted this interesting and important task to me. Our material for this research is now practically complete, owing to the addition to it of a large number of Stoliczka's original specimens, which have been sent to us for re-examination by Dr. King, the late Director of the Geological Survey of India.

The results, as regards palæontology, will shortly be published in the "Beiträge zur Palæontologie und Geologie" (edited by Professor W. Waagen), to which I hope to add a detailed account of those relating to the stratigraphical and zoological conditions. I will, therefore, at present restrict myself to a few general conclusions.

Owing to their peculiarly favourable position between the chalk of the Altantic and that of the Pacific area, the cretaceous rocks of Southern India are eminently adapted to serve as a starting-point for observations on the zoo-geographica condi-

1 Translation of paper published in the Jahrb k.k. Geol. Reichsanst 1894, Vol. 44, pt. 3.

2 M. Neumayr: Erdgeschichte, Vol. II, p. 390.

3 F. Stoliczka: Cretaceous Fauna of Southern India (Palæontologia Indic, 4 Vols. Calcutta, 1865-1873.

tions of later cretaceous times. Their fauna combines in itself the elements both of the eastern and of the western hemisphere, and thus serves as a connecting link between the two.

On the subject of the rich endemic fauna of the Indian cretaceous rocks, and the interesting survivors from older beds, which play such an important part in them, it would not be advisable to speak here.

The cretaceous rocks of Southern India fall into two main divisions: *viz.*, the larger Trichinopoly district, and the smaller and more northerly Pondicherry area—both south of Madras, and part of the so-called Coromandel coast, on the eastern side of the Indian peninsula.

During the geological survey of the Trichinopoly district,[1] it was found that a large number of the fossils collected bore a striking resemblance to forms occurring in Central Europe, and Stoliczka, in his work on the fauna, was thereby induced to unite no small proportion of the species — among the cephalopods no less than 25 per cent. — directly with European forms. Although on re-examination several of these identifications have proved erroneous, the affinities to the European fauna are still remarkable, more especially if we have regard not only to identical, but also to closely allied, forms. Extremely important also, and of great service in estimating the age of the beds of this system, is the fact that the succession of individual forms is to a great extent identical with that seen in Europe—a fact not fully appreciated by earlier observers.[2]

At the base of the Utatur group, just as in Europe at the base of the cenomanian, occur *Schlænbachia inflata* Sow. and several allied species, *Hamites armatus* Sow, *Turrilites bergeri* Brongn., etc. In higher beds we meet with an extraordinarily rich *Acanthoceras* fauna, of the type of *Ac. rhotomagense* Brong., while a large number of other well-marked forms, such as *Turrilites costatus* Brong., and *Alectryonia carinata* Lam. identify this horizon as the equivalent of the middle and upper cenomanian. The uppermost beds of the *Utatur group* I consider to be of lower turonian age, the typical *Acanthoceras* element having disappeared, and being replaced by Ammonites related to the European *Mammites nodosoides* (*Amm. conciliatus* Stol.) and to the well-marked *Inoceramus labiatus* Schloth. of the turonian.

The Trichinopoly group abounds in excellent specimens of Gastropods and Bivalves, which are, however, of little assistance in the determination of the horizons. Ammonites of central-European character are somewhat scarce, some very well-marked forms, however, being present. In the lower Trichinopoly group, *Am. serrato-carinatus* Stol. (allied to *Am. bravaisianus* Orb.) represents the turonian form *Prionocyclus*, while with it are associated typical forms of the important group of *Pachydiscus peramplus* Mant. The higher beds of the Trichinopoly group are marked as lower senonian by their gastropods and bivalves, but more especially by a *Schlænbachia* of the *tricarinata* type and a *Placenticeras* extending from the group of *P. placenta* Mort.

In the Ariyalur group, the most important cephalopods are the upper senonian

[1] H. F. Blanford: On the cretaceous and other Rocks of the South Arcot and Trichinopoly Districts; Madras (Mem. Geol. Surv. India. Vol. IV, pt. I.) Calcutta 1865.

[2] F. Stoliczka merely remarks that the Utatur group (the oldest of the three lower divisions) may be broadly compared to the cenomanian, the Trichinopoly group to the turonian and the Ariyalur to the senonian. (loc. cit. vol. IV, p. II.)

Pachydiscus and *Baculites*. In the highest division at Ninnyur, which ought preferably to be separated from the rest of the group,[1] the ammonites have disappeared while *Nautilus danicus* Schloth., and numerous gastropods and bivalves of more recent type, mark these beds as the boundary between the cretaceous and tertiary rocks.

To the Ariyalur group also I refer the great fauna of Pondicherry, which was considered by E. Forbes[2] to be of lower cretaceous age. Stoliczka, following Blanford,[3] endeavoured to distinguish, by their fauna, two horizons, the older of which, the Valudayur group, he characterised as cenomanian (Utatur group), while the other he considered to be of the same age as the Ariyalur group. In the course of time, however, it became evident that many of the fossils of the Valudayur group occurred in the Ariyalur beds of the Trichinopoly district, and Stoliczka was consequently much puzzled as to the true age of the Valudayur group, nor did he ever arrive at a solution of the difficulty.

During the past summer, I had the opportunity of studying Forbes' original specimens of the Pondicherry fauna, and came to the conclusion that all his specimens of ammonites from that district were derived from the hard brownish or bluish "Lumachelle" (fire-marble) and plainly from one single horizon. This may be proved by the similarity in the association of the forms and the mutual resemblance of the specimens. This horizon is Blanford's Valudayur group. In the abundant ammonite fauna of this series, we find not a single representative of the typical cenomanian fauna, so familiar in the Utatur group; we find no *Schlænbachia*, no *Acanthoceras*, no *Turrilites* while on the other hand we have the typical senonian *Pachydiscus*, a true *Sphenodiscus* (*A. siva* Forb.) very closely allied to the senonian *S. lenticularis*, as well as innumerable *Baculites vagina* and other ammonites. That the Valudayur group is in reality a development of the Ariyalur group, differing from it somewhat in lithological characters, may be proved by the following facts: (1) many of its most important fossils, such as *Pachydiscus egertonianus*, *Am.* (*n.g.*) *brahma*, *Baculites vagina*, etc., occur also in the Ariyalur group, whereas (2) the small number of species, which it contains in common with the Utatur group, has, on re-examination, been reduced to a few doubtful cases; and lastly, the gastropods and bivalves associated with the ammonites have considerable affinities to those of the Ariyalur, but none to those of the Utatur group.[4] Even in the Trichinopoly district the Ariyalur group overlaps the older cretaceous beds, which, further north, disappear beneath it, both in the S. Arcot district and also, as has now been proved, in the Pondicherry area. During the winter of 1893-1894, Dr. H. Warth undertook a revision of the survey of the Pondicherry district, and the fossils collected by him are now in course of transmission to Vienna, and will, it is hoped, throw much light on the question of the age of these rocks.

Lithologically, the upper beds exposed in Pondicherry (white sands and conglomerates) which were included by Blanford and Stoliczka in the Ariyalur group, differ from the Valudayur beds; nor could I find a single ammonite in

[1] This suggestion is also made by H. Leveillé in his small work: Geologie de l' Inde Francaise (Bull. Soc. Geol. France, 1890. t. XVIII) p. 144 ff.

[2] E. Forbes: Cretaceous fossils of Southern India (Transaction of the Geol. Soc. of London, II Ser., Vol. VII, London 1845-1856, Art. V. p. 165).

[3] H. F. Blanford. l. c., p. 151 ff.

[4] A. d'Orbigny considers the Pondicherry beds to be of senonian age. (Prodrôme de Paleontologie II., Paris, 1850, pp. 213, 215, 216, etc.)

Forbes' collection, while, on the other hand, Blanford discovered a *Nautilus danicus*, of the species occurring in the Ninnyur beds of the Trichinopoly district.

The question as to the connection between the cretaceous sea of southern India and that of Europe has already been repeatedly discussed. The careful examination of the Narbada cretaceous fauna, in which, after a cursory determination, Bose [1] believed that he had discovered Trichinopoly species, has proved its entire dissimilarity to that of the Trichinopoly-Pondicherry districts, while its echinodermata [2] have been shown to bear a striking resemblance to those of the cretaceous beds of Syria, North Africa, and Southern France, the typical members of the Mediterranean province. The theory of the former existence of land between the South of India and the North of Africa has thus gained additional evidence in its support. The upper cretaceous rocks of the northern and western mountain ranges of India have no connexion whatsoever with the Trichinopoly-Pondicherry series, while the Hippurite-limestone of Persia, Afghanistan and Baluchistan, [3] and the Glauconia-beds of Namcho Lake [4] in Tibet belong to the Mediterranean province. We must therefore seek elsewhere for a connection between the cretaceous seas of Central Europe and of Southern India.

The only remaining means of communication is therefore southwards through Africa,[5] and here we find the famous cretaceous beds of Natal, of which detailed accounts have been published, first by Baily [6] and subsequently by Griesbach.[7] The latter believed that he recognised in Natal all the three lower divisions of the cretaceous rocks of southern India, and he distinguished in the rocks of that country five separate horizons, lying unconformably on the Karoo beds:—

(*f.*) Limestone with *Amm. gardeni* Baily *Sp.*—Ariyalur group. (Senonian.)	
(*e.*) Soft sandstone with numerous bivalves and gastropods. (*Fasciolaria rigida* Baily, *Chemnitsia undosa* Forbes, *Protocardium hillanum* Sow., *etc.*)	—Trichinopoly group (Turonian.)
(*d.*) Sandstone with *Amm. umbolasi* Baily, *soutoni* Baily, *stangeri* Baily, *rembda* Forbes, *kayei* Forb., *Anisoceras rugatum* Forb. (*c.*) Soft brown sandstone (resembling *e*) with *Trigonia shepstonei* Griesbach. (*b.*) Calcareous sandstone with *Teredo*. (Base of the exposure.)	—Utatur group. (Cenomanian.)

During the past year, I examined Baily's original specimens in the collection of the Geological Society in London, and had also, through the courtesy of Mr.

[1] P. N. Bose, Mem. Geol. Surv., India, XXI, p. 43.

[2] P. M. Duncan. On the Echinoidea of the cretaceous strata of the Lower Narbada Region. (Quart. Journ. Geol. Soc., London, 1887, XLIII, p. 154.)

[3] *See* Mem. Geol. Surv. of India, Vol. XVIII, p. 34, Vol. XX, p. 140, 143 (Afghanistan), Vol. V., p. 116 (N.-W. Himalaya), etc.

[4] O. Feistmantel: On the occurrence of the cretaceous genus Omphalia, near Namcho Lake, Tibet (Records Geol. Surv., India, 1877, X, p. 21. ff).

[5] In Madagascar also, Newton discovered upper cretaceous species, among which were Ostreæ (O. vesicularis, O. pectinata, O. ungulata), all equally characteristic of the European senonian and of the Ariyalur group. (Quart. Jour. Geol. Soc., London, 1889, XLV, p. 333.)

[6] W. H. Baily: Description of some cretaceous fossils from Southern Africa (Quart. Jour. Geol. Soc., London, 1855, XI, p. 454 ff.)

[7] C. L. Griesbach: Geology of Natal. (Quart. Jour. Geol. Soc., London, 1871, XXVII, p. 60 ff.

G. C. Crick, the opportunity of seeing, at the Natural History Museum, a new collection of Natal fossils, far surpassing all collections hitherto made. From these it was evident that certain modifications of the views hitherto held were necessary. It was clear to me from Baily's specimens, that *Schlœnbachia stangeri* and *soutoni* do not belong to the lower cenomanian group of *Schlœnbachia inflata* Sow., as was originally supposed, but to the newer, lower senonian series of *Schlœnbachia tricarinata* Orb. In young forms *Schlœnbachia stangeri* Baily has three keels and only two sets of tubercles, one umbilical, the other external. Those of the latter series show on the ridge a faint linear extension (as in *Schl. tricarinata* type) which becomes more marked as the shell increases in age, and finally develops into a tubercle. Simultaneously, the earlier external series of tubercles extend down the side, while between them and the umbilical series yet another (a fourth) series appears. Finally, the two outer keels break up into a series of elongated tubercles, and even the median keel becomes somewhat varicose; the species then bears a strong resemblance to *Schlœnbachia texana* Rom. from the lower senonian of North America and Central Europe, while *Schlœnbachia soutoni* is a further development of the same type. Both these forms indicate a later age than that hitherto assumed for the beds in which they occur. That this view is correct, appears to me to be distinctly evident from the fact that in the new collection of Natal fossils, a beautiful and well preserved cast of a large fragment of *Schlœnb. stangeri* is associated in the same hand-specimen with *Puzosia gardeni* Baily: both of these species must therefore come from the same horizon. The forms *Puzosia rembda* Forbes, *Lytoceras kayei* Forb., *Anisoceras rugatum* Forb. are derived from the Valudayur group (senonian) of the Pondicherry district, while *Amm. umbolazi* Baily belongs to the somewhat involute *Schlœnbachia* (*Prionocyclus*) group of the lower senonian. (Next to these we have *Am. paon* Redtenbacher and *Am. haberfellneri* Hauer.)[1]

Baculites sulcatus Baily, which evidently did not come under Griesbach's observation, is also a senonian form allied to *Baculites teres* Forb. (*Baculites teres* Stol. from the Utatur group is entirely different.)

I attribute very great importance to the fact that, among the new material already mentioned is a very large specimen of *Amm.* (*n. g.*) *indra*, a characteristic and common form in the Valudayur group. I may also state here that the same species occurs in Vancouver, where it is associated with *Pachydiscus otacodensis* Stol. (an Ariyalur form). A complete account of the interesting facts connected with the investigation of the cretaceous fauna of South Africa will shortly be published by Mr. G. C. Crick.

The above observations are sufficient to justify the assertion that among the cephalopod fauna of Natal, so far as it is at present known, not a single species occurs indicative of a horizon earlier than lower senonian.

The horizon (*e*) has already been correctly identified by Griesbach as the palæontological equivalent of the Trichinopoli group. Almost all species common to both countries occur in India in the Upper Trichinopoli group. Since, therefore, of the known cephalopods of Natal, a large proportion belong to Ariyalur (Valudayur) species (*Puzosia gardeni*, *rembda*, *Lytoc. kayei* Forb., *Anisoceras rugatum*

[1] A. Redtenbacher: Die Cephalopodenfauna der Gosauschichten in den nordöstlichen Alpen. (Abhandl. der k. k. Geol. Reichsanst. Wien 1873. Bd. V., p. 131, 133.)

Forb., *Am. indra* Forb.), if the same connection also holds good in the Upper Trichinopoli group—as for example, that of *Schlœnbachia stangeri* and *soutoni* with *Schl. tricarinata* Stol. (non Orb.) of the *uppermost* Trichinopoli beds—then it appears that these latter forms extend beyond zone (*e*) and must be sought for in (*f*) with *Puzosia gardeni*.

There being no fossils on which to base an opinion, none can be offered as to Griesbach's horizons *b* and *c*.[1]

As in India, so also in Natal, which is so closely connected with that country, the cretaceous rocks bear a striking resemblance to those of the Atlantic area, both in their *Schlœnbachia*, which are allied to *Schlœnb*, *tricarinata* and *texana*, in their *Puzosia gardeni* (connected with *P. pseudo-gardeni* Schlüter), and also in several bivalves (*Protocardium hillanum* Sow., *Janira quinquecostata* Sow.) etc. It is, however, a remarkable fact that just as in the Trichinopoli and Ariyalur groups, so also in the fauna of Natal, the number of central European (or rather Atlantic) species is relatively much smaller than in the Utatur group.

A connecting link between the cenomanian of India and that of Europe is found in the well-known cretaceous rocks on the west coast of Africa, *viz*., Angola[2] and the Elobi Islands.[3]

The small *Schlœnbachia* fauna of the latter comprises, in addition to *Schl. inflata* (type), another specially Indian variety of this series, and in the same horizon in Angola occurs a *Stoliczkaia dispar* d'Orb., which corresponds exactly with an Indian form distinguished by Neumayr[4] as *Stol. clavigera*. At this stage the bivalve and gastropod fauna of the upper cretaceous beds of Angola begin to show signs of the influence of the Mediterranean province.

Here, however, the connection ceases between the cretaceous rocks of Southern India and those of Europe. Further north, in Morocco and Algiers, we find ourselves in the Mediterranean cretaceous area, the eastern extension of which we found in Narbada, Baluchistan, etc. In the western portion of this area may be seen unmistakeable signs of the connection between the cretaceous faunas of India and of Central Europe (*e.g.*, the fauna of the cretaceous rocks of the south of France, of Algeria, and also the Gosau beds); these, however, become less numerous as we approach the centre of the Mediterranean area. Blanckenhorn[5] figures an *Acanthoceras harpax* Stol. from Syria; I have examined the original specimen, which is in the possession of the Geological Institute of the University of Vienna, and find that, although closely allied to the Utatur form, it is not identical. His

[1] The adoption of a separate lower cephalopod zone (*d*) by Griesbach, is probably due to the fact that the section examined was the face of a cliff undermined by water (Izinhluzabalungu caves) and consequently masses from the higher beds had rolled down, and might be mistaken for independent outcrops. Baily, however, distinctly states that his *Am. Soutoni* was derived from a hard bed "high up the cliff." *l. c.*, p. 455.

[2] P. Choffat and P. de Loriol: Matériaux pour l'étude Stratigraphique et paléontologique de la province d'Angola. Mém. Soc. de physique et d'histoire naturelle de Genéve, Vol. XXX, I Partie, No. 2 1888.

[3] L. Szainocha: Zur Kenntniss der mittelcretäcischen Cephalopodenfauna der Inseln Elobi. (Denkschriften d. Akad. d. Wiss. Wien., 1885.)

[4] M. Neumayr: Ueber Ammoniten der Kreide, etc. (Zeitschrift d. deutsch. Geol. Ges. Berlin, 1875, p. 933.

[5] M. Blanckenhorn: Beiträge zur Geologie Syriens, Cassel, 1890, pl. X, fig. 3., pl. XI.

Schlœnbachia cf. *blanfordiana* (Ariyalur type)[1] is too badly preserved to justify any expression of opinion. The fact that the species with which we are concerned disappear in the eastern portion of the Mediterranean area proves that they found their way from the Atlantic, and to a certain extent, from Central Europe, into an otherwise isolated basin.

The cretaceous area of Southern India was connected with that of Central Europe west of the Mediterranean area.

The eastern boundary of the present Atlantic Ocean was already open in later cretaceous times, and a free interchange of fauna between Europe and the south of India was possible by way of Natal and the west coast of Africa.

Nor are there wanting links in the fauna to connect the eastern with the western side of the Atlantic Ocean, as also with Central Europe on the one side and Southern India on the other. For this purpose, great importance attaches to the cretaceous rocks of the Brazilian coast, with which, owing to the efforts of Charles A. White we have for some years been familiar.[2]

White describes the fauna of two separate cretaceous areas in Brazil; that of Sergipe, and the more northerly area of Pernambuco. He comes to no definite conclusion as to the age of these beds, merely assigning them generally to upper cretaceous times, and stating that they are more or less contemporary. Unfortunately, there is at present no detailed account of the stratigraphical conditions, Branner's observations[3] merely indicating several salient features. The area of Lastro, near Maroim, is very rich in important fossils, more especially cephalopods. The ammonites belong mainly to the genus *Schlœnbachia;* in fact, they all appear to be varieties of *Schl. inflata*, while many show affinities to forms found at Angola and figured by P. Choffat. From the same locality, White also describes 2 *Puzosia*, of which he identifies one as *A. planulatus*. From his figure, it appears not improbable that it may in reality be identical with Sowerby's cenomanian species. In the overlying beds, *viz.*, the sandstones of Arœira and the limestones of Garajau a *Puzosia* was found, which was identified by White as *Puzosia hopkinsi* Forb., and which is almost indistinguishable from *Puzosia welwitschi* Choffat, from the Schlœnbachia horizon of Angola. The occurrence of *Aucella brasiliensis* White in the cenomanian limestones of Garajaù is also very interesting, and forcibly recalls the appearance in India of an *Aucella*, *viz.*, *Aucella parva* Stol. in the beds of the same age. From another locality, connected with Lastro by an Echinoid (*Echinobrissus freitasi* White), a very interesting ammonite had already been described by Hyatt under the name of *Buchiceras Harthi*, and was subsequently figured by White. This figure leaves no doubt that we are dealing with an *Olcostephanus*, in fact one of the peculiarly Indian type of *Am. rudra* Stol. (Neumayr's Stoliczkaia), while the form *Am. pedroanus* White, which is associated with it in Brazil, bears a striking resemblance to *Acanthoceras footeanum* Stol. of the Utatur group. From a calcareous sandstone assigned by Branner to the Lastro horizon, but by White to the succeeding zone—which corresponds better with the palæontological relations—an *Am. folleatus* and an *Am. offarcinatus*

[1] M. Blanckenhorn: *l. c.* pl. xii, Fig. 1, p. 134.

[2] Ch. A. White: Contributions to the Palæontology of Brazil. (Archiv. do Museu Nacion, Janeiro. vol. vii, 1888.)

[3] M. Branner: The Cretaceous and Tertiary Geology of the Sergipe-Alagoas basin of Brazil. (Transact. of the Americ. Philos. Soc. Philadelphia, 1889, vol. xvi, p. 429 ff.)

the plateau of Assam,[1] beds which are closely allied by their fauna to those of the Trichinopoli district, the fossils indicating, according to Stoliczka, the presence of strata representing both the Utatur and the Ariyalur groups.

The characteristic fossil of the cenomanian beds of Europe, West Africa, and Southern India, *viz.*, *Schlœnbachia inflata* Sow., was found in the flysch-like sandstones of the Sandoway district of the peninsula of Further India.[2]

In Borneo, upper cretaceous beds occur which are characterised by an abundance of Nerineæ, and yield several species of fossils found in Southern India, amongst which are characteristic Ariyalur forms, such as *Nautilus trichinopolitensis* Blanf. Martin assigned the cretaceous rocks of Borneo to his Eastern Asiatic Province, extending from Japan, through Southern India, to Natal.[3]

In Australia,[4] the cretaceous rocks are exposed over a large area, and have from time to time yielded a considerable number of cephalopoda, including several typical lower cretaceous forms, such as *Crioceras*, etc., and consequently the beds in which they occur, the so-called "Rolling Down Formation," have been assigned to that age. From other localities, however, fossils have been obtained (*e.g.*, a *Schlœnbachia* of the group of *Schl. inflata*, and several Puzosia) which recall the cenomanian forms of India, and it is quite possible that an Indian fauna may alse be discovered in Australia. The supposed upper cretaceous beds of that country are very poor in fossils.

So far as the cretaceous fauna of Eastern Asia is known, as for example at Jesso[5] and Sachalin,[6] it is of a well-marked Indian type. A comprehensive work by Jimbo on the cretaceous rocks of Jesso[7] appeared a few months ago, and considerably adds to our list of Indian types of ammonites. An especially important part is played by *Lytoceras* of the *Lytoceras Sacya* group which is also represented in India by a great variety of forms; we may also mention *Phylloceras*, *Pachydiscus*, etc., while *Acanthoceras*, of the *rhotomagense* type, is no longer unknown in the Pacific area. A large number of allied, as well as several identical species connect the cretaceous rocks of Japan and Sachalin to the Utatur group; thus we find *Lytoceras sacya* Forb., *Phylloceras velledæ* Mich., and *Acanthoceras rhotomagense* var. *asiaticum* Jimbo, also in the Utatur group. We can also trace a connection with the Trichinopoli group, for a form allied to *Pachydiscus peramplus* has been found at Jesso, while large and numerous specimens of a similar form had already been discovered at Sachalin. Very large also is the number of Japanese species of *Pachydiscus* which are closely allied to, or rather identical with Ariyalur forms.

[1] H. B. Medlicott: Geological Sketch of the Shillong Plateau in N. E. Bengal. (Mem. Geol. Surv. India. VII. Calcutta. 1871. p. 181. ff.).

[2] W. Theobald. Records Geol. Sur., India, V, Calcutta, 1872, p. 82.

[3] K. Martin. Die Kreideformation von Martapoera (Borneo). Sammlungen des Geol. Reichsmuseums in Leiden. Ser. I, Vol. IV, 1889, Heft 5, 6, p. 142.

[4] R. L. Jack and A. Etheridge. The Geology and Palæontology of Queensland and New Guinea. London 1892, p. 390 ff.

[5] M. Jokoyama. Versteinerungen aus der Japanischen Kreide.(Palæontographica, XXXVI Cassel 1889-90, p. 159 ff.

[6] F. Schmidt. Die Petrefacten der Kreideformation von der Insel Sachalin (Mem. de. l' Académie Impériale des sciences de St. Petersbourg, VII. Ser. Tome, XIX. Nr. 3, 1873.

[7] K. Jimbo. Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido. (Palæontologische Abhandlungen. Bd. VI, Heft 3, Jena, 1894.)

So striking is this fact, that Harada, Jokoyama, and now also Jimbo have concluded that the fauna of Japan must be considered as the result of an intermingling of forms from every possible horizon of upper cretaceous age, and that no division of the rocks into distinct horizons with characteristic fauna, can be attempted. But until we have a detailed account of these areas, little importance must be attached to the above statement, for in cretaceous beds, widely separated from India, *viz*., in the Pacific section of North America, the Indian species occur in a succession almost identical with that seen in the beds of that country.

An especial interest attaches to the coal-bearing cretaceous rocks of Queen Charlotte's Islands [1] in the North-Eastern Pacific. The most fossiliferous bed of the cretaceous rocks of that area is Richardson's division C., which strongly resembles the Volga Series of Russia, not only in the occurrence of *Aucella*, to which fact the greatest importance has hitherto been attached, but also in the presence of many ammonites. Thus, for example, *Am. skidegatensis* Whiteaves [2] differs but very slightly from *Olcostephanus pallasi* Kaiserling, while several other varieties of *Olcostephanus* occur, and I cannot accept Whiteaves' view that the bed C. is equivalent only to the Gault. In the highest zones of this division can be seen numerous unmistakeable signs of a connection with the Utatur group; we find the same *Lytoceras Sacya* as in Japan and India, as well as *Schlœnbachia inflata*, *Lytoceras timotheanum* May, etc.

The overlying conglomerate, which is apparently the equivalent of the Dakota group is almost entirely devoid of fossils, but the higher shale beds, the "Upper Shales," have yielded *Inoceramus problematicus* Schloth., a common form in the Colorado group of the Atlantic section of North America and in the turonian of Europe.

We have, therefore, in Queen Charlotte's Island, a conformable series, extending from the lowest to the upper cretaceous beds. The most recent investigations also reveal very similar conditions in Northern California.[3]

To the west of the Upper Sacramento Valley a continuous series of cretaceous rocks is exposed: first, the Knoxville beds with *Aucella*; above these, the Horsetown beds, and at the summit, the upper cretaceous Chico group. The Knoxville and lower Horsetown beds yield lower cretaceous fossils, while in their uppermost horizons, the latter beds contain *Schlœnbachia inflata* Sow. and *Lytoceras sacya* Forbes, exactly as in the upper horizon of division C. in Queen Charlotte's Island. The lower Chico beds of Mt. Diablo have for some time been known to contain an *Acanthoceras* of the *rhotomagense* type, *viz*., *Acanthoceras turneri* White, [4] which species I also obtained from the Utatur group of India.[5] In the upper beds of the Chico group, in addition to baculites of undoubted senonian facies, is found *Pachydiscus newberryanus* Gabb (non Meek), which is very nearly allied to *P.*

[1] J. F. Whiteaves. Mesozoic Fossils. (Geol. and Nat. Hist. Surv. Canada) Vol. I, pt. I and III Montreal, 1876 and 1884.

[2] J. F. Whiteaves. l. c. Pt. I, pl. IX, fig. 1 p. 34.

[3] J. S. Diller and T. W. Stanton. The Shasta-Chico Series, (Bulletin of the Geol. Soc. of America). Vol. V, pp. 435-464. Rochester, 1894.

[4] Ch. A. White: On invertebrate fossils from the Pacific coast. (Bulletin U. S. Geo. Surv. No. 51 Washington 1889. pl. V. p. 26.)

[5] The identity of the two forms was confirmed by Ch. A. White, to whom I sent a figure of the Indian specimen.

otacodensis Stol. It is a very interesting fact that the Chico group, the lowest beds of which consist entirely of conglomerate and sandstone, overlaps the older strata of the so-called Shasta-Chico Series and over extensive areas in Washington, Oregon and California, lies directly on the older metamorphic rocks. The occurrence of a cenomanian *Acanthoceras* in the lower Chico beds, and of the lower cenomanian forms, *Schlœnbachia inflata* and *Lytoceras sacya* immediately below them proves that this overlap was almost contemporary with that of India, West Africa and Europe, etc.[1] The Chico group is known to extend to latitude 29° 30' N. (Lower California.) Beds resembling those of the Chico group, occur also further north in the Island of Vancouver,[2] where they are characterised by the number and excellence of their fossils. In the British Museum, in an old collection made by Hector and mentioned by Whiteaves, but not hitherto examined, I observed not only an excellent specimen of *Am. indra* Forb., but also, from the same beds the typical *Pachydiscus otacodensis* of the Ariyalur group, not hitherto identified in North America, and several other *Pachydiscus* forms, some of which were new, as well as *Baculites occidentalis* Meek, which is closely allied to the Indian *Baculites vagina*, etc. Whiteaves mentions the occurrence of *Puzosia gardeni* Forb. in the Chico group of Vancouver, while his *Lytoceras jukesii* (?) Sharpe is apparently identical with *Lyt. kayei* Forb.: the number of Indian species is therefore very considerable. So far as the fauna of the Pacific area of North America has hitherto been identified, the succession of the horizons is very similar to that seen elsewhere. In the upper Horsetown beds occur *Schlœnbachia inflata* and *Lytoceras sacya*, and next above them, in the lower Chico group, *Acanthoceras* followed in the upper *Chico group* by *Pachydiscus* and baculites.

Our knowledge of the other cretaceous rocks on the Pacific side of America is very meagre. In Chili unmistakeable upper cretaceous beds occur. In the Natural History Museum in London, I saw the specimens of *Baculites vagina* Forb.,[3] from Conception Bay, which are mentioned in Darwin's work on South

[1] Since a single "Shasta-Chico Series" has been established, extending from the lowest to the upper beds of cretaceous age, the question as to the date of the folding of the Sierra Nevada and coast ranges has assumed a new aspect. If the altered *Aucella* (Mariposa) beds of the Sierra Nevada, which are unconformably overlapped by the Chico beds, are of the same age as the lower Knoxville beds of the Shasta-Chico series, then the folding of the Sierra Nevada and the coast ranges would certainly be intercretaceous, a view which formerly met with general acceptance. Folding then took place simultaneously with that in Mexico, while at the same time, uninterrupted sedimentation was proceeding in the Upper Sacramento Valley and further to the North. (Queen Charl. Isl., Rocky Mts. and British Columbia). After the completion of the folding, the sea again flowed over the newly-formed mountains, and upon them the Chico beds were laid down. According to another view, however, the Mariposa beds are of Jurassic age, and consequently older than the Knoxville beds, and the folding took place previous to the deposition of the latter. See H. W. Fairbanks: The pre-cretaceous age of the metamorphic rocks of the California Coast Range, (Americ. Geologist. March 1892. p. 153 ff.). At present our data are too scanty to enable us to arrive at a decision of any value. This one important fact, however, is certain, that in upper cretaceous times (Chico period) the Sierra Nevada formed the western coast of a continent, the Great Basin, which extended eastward from that range.

[2] J. F. Whiteaves l.c. Pt. II. On the fossils of the Cretaceous Rocks of Vancouver, etc. Montreal, 1879.

[3] Ch. Darwin: Geological observations on the volcanic islands and parts of Southern America, 2 edit., London, 1876, p. 397.

America. These differ in no particular from the Indian specimens. At the Geological Congress held recently in Zurich, Prof. Steinmann,[1] speaking on the cretaceous rocks of Chili, said that, on investigation, he had indentified *Phylloceras* and *Lytoceras* forms connecting the beds of that country with the Utatur group of India. There may therefore be in the upper cretaceous rocks of Chili both Utatur and Ariyalur forms.

In general type, the cretaceous rocks of the Pacific area can be readily distinguished from those of the Atlantic province. Time has proved indeed that almost all species occurring in the one are also represented in the other, but often in a much less degree. Thus, for instance, *Schlœnbachia* and *Acanthoceras*, although not unknown in the cenomanian of the Pacific area, occur but rarely, and are quite out-numbered by a profusion of *Phylloceras* and *Lytoceras* forms, (the latter more particularly of the *Lyt. sacya* type). On the other hand *Desmoceras* and *Puzosia*, which are of rare occurrence in the upper cretaceous rocks of the Atlantic area, are here comparatively common, while *Holcodiscus*, which is not known to occur in the upper cretaceous beds of the Atlantic area, is represented in India by an abundance of forms. *Pachydiscus* and *Baculites* are more or less equally distributed in both hemispheres, being represented, however, by different species. It is impossible, therefore, nor would it be advisable, to enunciate shortly a hard-and-fast distinction, which on further investigation might prove to be erroneous, for only quite recently has it been shown by Jimbo that the true Atlantic type of *Placenticeras* and *Acanthoceras* (of the *rotomagense* group) occurs also in Japan.

On the whole, however, the cephalopod fauna of the upper cretaceous rocks in the Pacific area is not so rich in new forms as is that of the Atlantic province, the majority being closely connected with lower cretaceous forms; and this "conservative tendency," noticed by Neumayr[2] in the cretaceous fauna of Southern India, is, so far as we are at present aware, to a great extent peculiar to the Pacific area. The commingling of both types, which in India was so intimate that they almost balanced, is quite unknown in the cretaceous rocks of the west coast of America, which are much more closely related to the Atlantic area than are those of India.

The great difference between the cretaceous rocks of California and those of the Rocky Mountains, which are of the Missouri type, has long been known, and American geologists completely separate these two areas,[3] not only on account of the constitution of their fauna, but also on account of their geological conditions. As we approach the Great Basin, the cretaceous beds of the Rocky Mountains and of the Colorado plateau increase in thickness, and we find intercalated, at widely separated horizons, seams of coal and beds containing brackish or fresh-water shells; thus indicating the proximity of the western coast of the ancient continent, the Great Basin, which was subjected to folding in post-jurassic times, and from which cretaceous beds are entirely absent; while on the other side of the Sierra Nevada, we meet with the completely different cretaceous rocks of California.

[1] G. Steinmann: Procès—Verbaux des Séances des Sections 30. 8. Congrès Géologique international VI. Session à Zurich, 1894 pp. 6, 10.

[2] M. Neumayr: Erdgeschichte, Bd 2, p. 390.

[3] See Ch. A. White (Bull. U. S. Geol. Surv., No. 15, p. 30.)

An interesting addition to these facts was contributed by Hill,[1] in his investigations of the cretaceous rocks of Mexico. He discovered that the lower cretaceous (Comanche series of Texas) of the Mexican Sierras almost extends from ocean to ocean. Before the deposition of the upper cretaceous beds, however, these rocks were subjected to folding, and the next series (upper cretaceous) was then laid down, which, as may be seen in the Missouri district in the east, lies unconformably upon them. During upper cretaceous times, the lofty mountain folds of the Great Basin region of North America formed dry land, extending as far as British Columbia.

In the north of British Columbia we encounter somewhat different conditions. It has already been stated that the Upper Shales of Queen Charlotte's Islands yield *Inoceramus problematicus* Schloth., which is also frequently met with in the cretaceous rocks of Missouri. On the mainland of British Columbia between the parallels of 49° and 51° 30′, Dawson discovered a bed resting on the *Aucella*-bearing Kootanie Series, which latter is the littoral representative of the Shasta group, or more particularly of Div. C of Queen Charlotte's Islands. This bed is a conglomerate similar to that found in Queen Charlotte's Islands, and is overlain by the clay of the Colorado group and by upper cretaceous beds extending to the Laramie Series.

In the same locality, it was also possible to identify with certainty upper cretaceous beds of Atlantic type resting upon lower beds of Pacific type, and the occurrence of *Inoceramus problematicus* in Queen Charlotte's Islands is a proof that the same conditions prevail there also. Hence we see that a connection resulting in overlap existed between the Atlantic beds and those of the Pacific area, which during lower cretaceous times extended to the eastern spur of the Rocky Mountains.[2] The interchange of fauna, thereby rendered possible, seems however to have been quite insignificant, the admixture in the Chico group of forms from the Atlantic portion of North America being very trifling.

The conditions prevailing in the northern districts of South America and in the Antilles, are very interesting. In Jamaica, corals[3] have long been known to occur of which several are identical with those of the Gosau beds, while hippurites are associated with them, and an *Actæonella* also has been stated to occur; all the above being fossils which undoubtedly occur in the Mediterranean cretaceous area. In striking accord with the above facts is the discovery in Peru[4] of an *Actæonella* and

[1] R. Hill: The Cretaceous Formation of Mexico and their relation to North American Geographic Development. (Am. Journ. of Science, 3, Ser., XVI, No. 268, 1893, p. 307).

[2] J. F. Whiteaves, too, finds that the upper cretaceous rocks are more nearly related to those of the eastern area than are the rocks of the more southern Chico group of California (l. c. Vol. I, Pt. II, p. 187) which is further evidence in favour of the above connection.

On the whole, Whiteaves agrees with Gabb in supposing that communication was carried on through the southern area, and adduces as evidence in support of his view the fact that cretaceous rocks occur to the west of the Sierra Madre in Mexico. But in the Chico period the coast extended much further west, embracing Lower California, while the fauna also of that district is entirely different to that of Mexico and Texas.

See also Ch. A. White: Notes on the Mesozoic and Cenozoic Palæontology of California (Bull. U. S. Geol. Surv. No. 15, Washington 1885), p. 30, and R. Hill; Cret. Format. of Mexico etc., p. 319.

[3] S. M. Duncan and G. P. Wall; A notice on the Geology of Jamaica (Quart. Journ. Geol. Soc., London, XXI, 1865), p. 2, ff.

[4] W. M. Gabb; Description of a collection of fossils made by Dr. A. Raymondi in Peru (Journ. Acad. Nat. Science Philadelphia, 2, Ser. Vol. VIII. Part III, Art. X, 1877, see pl. 36, fig. 1, a, b, p. 264 etc.)

of typical Mediterranean ammonites, closely connected with "*Buchiceras*" *syriacum* Buch. Such a fauna cannot fail to have been derived from the Mediterranean, and the assumption is therefore inevitable that an arm of the sea stretched across America, most probably in the neighbourhood of the Antilles and the modern Cordillera region of the northern part of South America, thus rendering possible the migration into the Pacific area of exclusively Mediterranean types. It was formerly supposed that the form "*Buchiceras*" *harttii* Hyatt, found in Brazil was connected with those discovered in Peru, and consequently it was assumed that communication had originally been possible by means of the valley of the Amazon. We can now however, recognise the former existence of two arms of the sea, which divided America as it existed at that period into two great insular portions, constituting the boundary between the Pacific and Atlantic Oceans.

The cretaceous rocks of Southern India are more or less closely connected with a very large number of rocks of that age occurring in other countries, and are consequently well adapted to serve as their type. The European beds on the other hand, being merely a typical sub-division of the Atlantic area, are of but little service in this respect, and frequently fail us if we endeavour to correlate them with the cretaceous rocks of the Pacific. The great importance of the cretaceous beds of Southern India was therefore speedily recognised, but their connection with those of the Atlantic area has been much under-estimated.

In reality, the fauna of Southern India comprises the most important types of both the great areas and thus serves as a connecting link between them.

The marked contrast between the cretaceous rocks of the Atlantic area, and those of the Pacific consists not only in the great difference of extension of the overlap, but also in the independence of their respective fauna. This is particularly striking in America, but disappears to the south of the ancient Indo-African continent.

I have now stated in general terms the most important facts bearing on the geographical conditions which prevailed in upper cretaceous times. No other system offers such a profusion of material for a detailed reproduction of those conditions, and it is my intention, as soon as possible, to embody these in the form of a chart.

In conclusion I should like to enter briefly into a few general questions.

Neumayr ascribes great importance to the influences of climate, more especially as regards the horizontal distribution of the Ammonoidea. This question has received a considerable amount of attention,[1] and it is now probable that the dispersion of the cephalopods was due less to the effects of climatic influence than to those of the distribution of land and sea, and the consequent facilities for migration. The ammonite fauna of Central Europe is at least as intimately connected with that of Southern India, as with that of the Mediterranean. Now the climate of Central Europe cannot have differed widely from that of the Mediterranean, while on the other hand that of Southern India was tropical, and the similarity in fauna must be due to migration of species from one hemisphere to the other by way of Natal. Even disregarding any possible deductions from the present climate, we can still establish

[1] S. Nikitin. Einiges uber den Jura in Mexico und Centralasien. (Neues Jahrb., Vol. II, 1890, p. 273, ff.)

A. Tornquist. Fragmente einer Oxfordfauna von Mtaru (Deutsch Ostafrika). Jahrb. der Hamburger wissenschaftlichen Anstalten. X. 2. Hamburg, 1893, p. 24.

the tropical character of the cretaceous fauna of Southern India, both by means of the reef-building corals and also, though in a lesser degree, by the presence and luxuriance of the gastropod and bivalve fauna. The argument in favour of a tropical climate based by Neumayr on the occurrence of *Phylloceras* and *Lytoceras*, applies equally well to the whole Indo-Pacific region. In that area, these forms are found in districts which, according to Neumayr, during the preceding Jurassic and lower cretaceous periods were closely connected with the Volga beds, that is to say, with the Northern basin. The less extensive faunas, inhabiting smaller and more isolated seas, may possibly have been less independent of climatic influences; but it is very difficult to decide with any degree of certainty the amount of importance to be attached to this factor.

The wide distribution of the Ammonoidea, which so complicates the question of climatic influence, induced Professor J. Walther[1] to believe that on the death of the ammonites, their floating shells became filled with air, and were borne hither and thither by winds and currents. He consequently concludes that their wide distribution was due, not to migration during life-time, but to a subsequent transportation of the empty shells. He even considers himself justified in propounding the theory that "the Triassic, Jurassic and Cretaceous systems may, for the most part, each be distinguished by a single species of ammonite, and may thus be recognised with facility in any part of the globe": and again," during a given geological period, some one species of ammonite was uniformly distributed over the whole sea-floor, and after a short existence, became everywhere simultaneously extinct and was everywhere simultaneously replaced by a new species." The above statements involve a gross exaggeration of the true state of the case, for if we study the fauna of any given period over the whole earth, we find that in reality the phenomena are highly complicated. In the majority of cases, those species by means of which we correlate widely separated areas, are not identical, but are merely closely allied forms: *i.e.*, geographic variation involves variation of species.

The more careful our observations, the more frequently do we find that in numerous cases, species originally supposed to be identical, are in reality only members of similar groups, which may be distinguished from one another by certain constant characteristics. Thus, for example, we find in India neither *Acanthoceras rhotomagense* Defr., *Mammites nodosoides* Schloth, *Pachydiscus peramplus* Mant., *Schlænbachia tricarinata* Orb., *Placenticeras syrtale* Mort., nor *Baculites anceps* Lam.; closely allied forms, however, do occur, and these are found in an exactly similar stratigraphical relationship, and are evidently their representatives. Very similar examples of this may be seen if we compare the cretaceous fauna of Brazil, Japan or North America with that of India.

It is, however, undeniable that there are species, several of which I have already had occasion to mention, which, by their constant characteristics, may be recognised in almost every part of the world. Thus *Lytoceras timotheanum* May has been found in Europe, India, Sachalin, and Queen Charlotte's Islands. In Europe, it is connected with contemporaneous and also with older forms, while its descendants are found in India in the Trichinopoli and Valudayur groups; nearly allied forms also occur at Jesso. If, however, its presence in any given area were due to

[1] J. Walther: Einleitung in die Geologie als historische Wissenschaft, II. Th. Jena., 1893-94. (Die Ammoniten als Leitfossilien, p. 508. ff.)

marine transportation, it would there be isolated and not found in association with allied forms. Many other examples of a similar nature are to be seen in *Desmoceras, Puzosia, Pachydiscus, Acanthoceras, Schlœnbachia, Hamites*, etc. Any further demonstration of the fact would, however, be valueless without palæontological details. Hence we see that there are certain widely dispersed species of ammonites, which are found to be distributed in such a manner that we are compelled to assume an independent migration.

Very similar conditions prevailed during Triassic and Jurassic times: and the above facts prove that in all such cases the animals lived in the localities in which their remains have been found. The possibility of the occasional transportation of the empty shells need not be contested. Walther's theory, however, has no special bearing on the question of the zoo-geographical conditions.

If we compare the horizontal distribution of the ammonites with that of other forms of animal life, we find that it is by no means so abnormal as to necessitate an explanation other than that of simple migration. Thus, for example, in Southern India, associated with European ammonites, we find also European brachiopods, bivalves and gastropods, though certainly in smaller numbers. If again, we compare the conditions prevailing at the present day, we find numerous striking examples of the wide distribution of many marine shells. Thus, for instance, species are now living which are common to Natal, Ceylon, the Philippines, Japan, and even the coast of Australia;[1] and Fischer draws special attention to a considerable number of gastropods which are found both in the Indian Ocean and at the Antilles.[2] Similar, if less striking examples might be added—there is even an unmistakable resemblance in the distribution of the modern fauna[3] which, however, is not to be wondered at, if we consider the great resemblance existing between the geographical conditions during later cretaceous times and those prevailing at the present day.

Report on the Experimental Boring for Petroleum at Sukkur, from October 1893 to March 1895, by T. H. D. LATOUCHE, B.A., *Superintendent, Geological Survey of India.*

The actual drilling of the Sukkur boring was commenced on the 19th December 1893, the previous two months having been spent in bringing down from Babar Kuch the boring plant, which had been in use at the Khattan oil-wells, in selecting and repairing such portions of it as were suitable for the Sukkur boring, and in erecting the drilling rig and derrick. The site had been provisionally selected by Dr. King, late Director, Geological Survey. The reason of this choice was not that there was a greater probability of obtaining oil at that spot than at any other in the neighbourhood of Sukkur or Rohri, for at that time no surface indications of

[1] P. Fischer: Manuel de conchyliologie. Paris, 1887, tome. 1. p. 158.
[2] P. Fischer. l. c. p. 177.
[3] See Fischer's chart, p. 126.

the presence of oil had been found anywhere in Upper Sind; it was merely a matter of convenience, for, being close to the North Western Railway workshops, repairs to the machinery could be carried out with as little delay as possible, while it was also at a convenient distance within the area of outcrops of the upper nummulitic limestone, the base of which forms a well-defined horizon for comparative measurements in relation to sections or borings in other localities.

Progress of the boring.

In the first place a well or sump was excavated down to the level of the surface water, which was found at a depth of about 10 feet. A length of 8-inch casing was then put in and sunk through the alluvial sandy clay overlying the limestone until the eroded surface of the latter was struck at a depth of 38 feet 6 inches. Now that experience has been gained of the nature of the rocks beneath the limestone, it is evident that it would have been better to have started with a larger diameter of casing than 8 inches, as this would have greatly facilitated subsequent operations; but, at the time the boring was begun, it was not anticipated that the hole would have to be lined with casing to so great a depth.

After the limestone was struck on the 23rd December 1893, at which date work was stopped till the end of the year, the progress made may be summarised as follows:—

Month.	Progress made.		Total depth.		REMARKS.
	Ft.	Ins.	Ft.	Ins.	
January 1894 .	281	0	324	0	The base of the limestone was reached at 140 feet from surface. The boring then entered beds of shaly blue clays, with thin bands of limestone and nests and veins of gypsum.
February " .	76	0	400	0	Drilling much retarded by clogging of tools. Six-inch casing was put in to a depth of 167 feet.
March " .	17	7	417	7	Greater part of month spent in substituting 7-inch casing for the 6-inch and in putting down the latter to the bottom of the hole.
April " .	75	5	493	0	A thick band of limestone was passed through at 409 feet, which prevented the casing from going down. The casing had to be drawn out and the obstruction cut away.
May " .	*nil*		...		The whole month was spent in lining the hole with 6-inch casing. The tools became jammed in the hole on the 12th, and were not recovered till the 21st. The 6-inch casing was put down to 440 feet, but could be sunk no further, and a string of 4⅝-inch casing was therefore put in.
June " .	47	0	540	0	Drilling proceeded till the 8th, when the 4⅝-inch casing refused to go further. The 6-inch casing was driven down to 464 feet.

Month.	Progress made.		Total depth.		Remarks.
	Ft.	Ins.	Ft.	Ins.	
July 1894 .	5	0	545	0	The whole month was spent in trying to get the 6-inch casing past the obstruction at 464 feet. On the 13th the sand pump was lost in the hole, and was not recovered till the 28th. Subsequently, the 6-inch casing was driven down to 525 feet.
August " .	87	0	632	0	The 4½ inch casing was put in again. From the 6th to the 23rd repairs were being made to the engine and boiler.
September " .	113	0	745	0	Progress was more rapid this month, as the casing followed the tool down and was not stopped by bands of hard rock.
October " .	134	6	879	6	Indications of gas were observed at about 785 feet, and water was struck at about 865 feet.
November " .	78	0	957	6	The 4½-inch casing, which had now reached a depth of 917 feet, would not go further, and it was therefore pulled out and the lining of the hole continued with 6-inch casing by the aid of an under-rimer.
December " .	nil		...		Putting in the 6-inch casing. Repairs to the engine and boiler were done between the 6th and 15th.
January 1895 .	6	0	963	6	Putting down 6-inch casing. Struck a band of hard limestone at 958 feet.
February " .	79	0	1,042	6	Drilling proceeding fairly steadily, though slowly. The band of limestone at 958 feet proved to be only 20 feet thick. The hole was lined with 6-inch casing to 1,023 feet.

Since the beginning of March progress has again been very slow, and up to the present about 40 feet have been drilled. Two more lengths of 6-inch casing have been put in, making a total of 1,056 feet now in the hole, but these last two lengths have been driven down with much difficulty, and it is hardly likely that much more casing of this size can be used. It is, however, more than we expected it would be possible to introduce, and of course it is a great advantage to have the hole perfectly clear to such a depth, for it will considerably facilitate the progress of the smaller casing, which will shortly have to be put in.

Character of the strata beneath the limestone.

The shales and clays beneath the limestone are of very uniform character throughout the whole distance—about 940 feet—passed through up to the present, the only exception being the occurrence of thin bands and nodules of hard grey limestone; and th re can be no doubt, as pointed out by Mr. Griesbach, that they are the same beds as those found in a similar position beneath the upper nummulitic limestone in Baluchistan, as, for instance, in Mudgorge on the Hurnai Railway. What their thickness may be at Sukkur it is impossible to say, for the

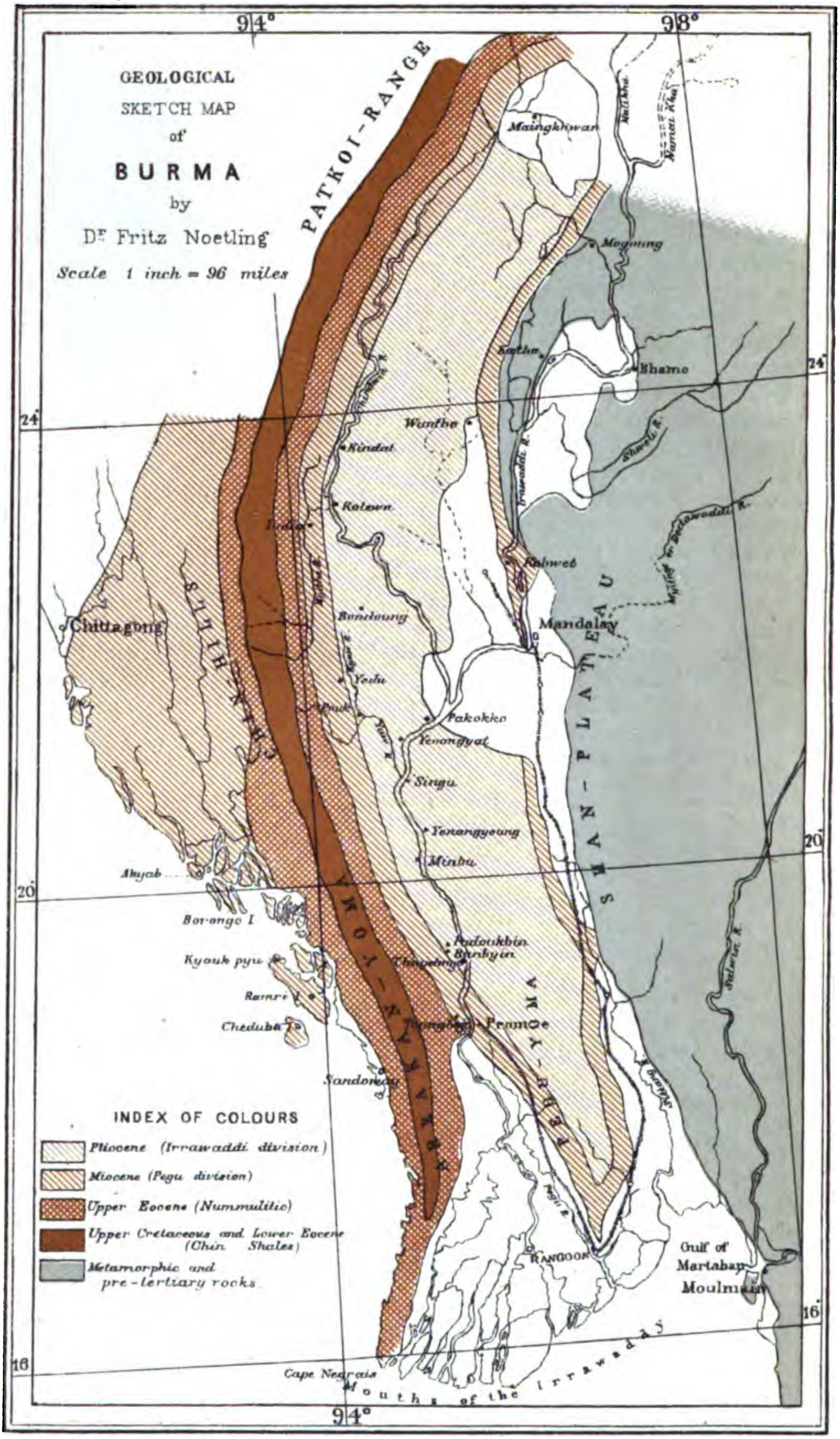
different members of the tertiary system vary considerably in thickness in different localities, and no measurements made in the hills to the west of Sind can be relied on to furnish an estimate of the thickness at Sukkur. They may continue without much change for another thousand feet, or, again, the underlying rocks, which it is to be hoped are of more solid character, may be reached at any moment.

Future prospects of boring.

Under these circumstances it is difficult to offer any opinion as to the future prospects of the boring, that is to say, as to the depth to which it should be carried before hopes of a successful issue are abandoned. But a discovery has quite recently been made in the neighbourhood of Rohri, on the other side of the Indus, which seems to point to there being a certain depth at which oil, if it exists in any quantity, should be met with, and to this depth I think that the boring should certainly be carried; and now that so much of it has been lined with 6-inch casing, there should be no great difficulty in doing this. I have already reported on the discovery alluded to, but it may be well to call attention to the facts here, and the conclusions I have drawn from them so far as they affect the Sukkur boring.

Traces of oil at the surface near Kundra.

My attention was recently called by His Highness the Mir of Khairpur to the fact that some peculiar gas had been observed for many years to issue from the soil at a spot about three miles to the west of Kundra, a village eight miles south of Rohri. I visited the place soon afterwards and noticed that the gas appeared by its odour to be similar to that observed in the boring at Sukkur; and recently I had a well dug at the spot so as to reach water, which was found at about 20 feet from the surface. After reaching a depth of 16 feet or so the gas, which is apparently carbonic acid, as it does not support combustion, issued in such volumes as to prevent the men working in the well, and the sinking had to be carried on from above. On examining the water, after emptying it out and allowing it to flow in again several times, distinct traces of oil appeared on the surface in the shape of iridescent films, and, on dredging up the sand from the bottom, these films could be seen oozing out from it and spreading over the surface of the water. The place is well out on the alluvium of the Indus valley, no solid rock being seen anywhere between it and the ridge of limestone running south from Rohri, which lies at about six miles distance to the east. Now, if we knew the thickness of the alluvium and the dip of the beds, it would be easy to calculate from what horizon in the rocks beneath the limestone these traces of oil escape, supposing that they escape from the outcrop of the rocks beneath the alluvium and do not rise through some fissure. Consequently, we should know at what depth we might expect to meet with them in the Sukkur boring. Estimating the thickness of the alluvium at 300 feet, and the dip at 2° to the east, which is about the average dip seen in the hills, the thickness of beds between the base of the limestone and the horizon at which the oil escapes works out to about 1,500 feet; and, as the base of the limestone at the Sukkur boring is 140 feet from the surface, the total depth to be drilled in order to reach that horizon should be a little over 1,600 feet. Of course the alluvium may be of greater or less thickness than I have estimated. This can only be determined by a boring at the spot; but the difference, whatever it may be, should be added to or substracted from the estimate above given, in order to determine the depth to which the Sukkur boring should, in my opinion, be carried before being abandoned.


GEOLOGICAL
SKETCH MAP
of
BURMA
by
Dr. Fritz Noetling
Scale 1 inch = 96 miles
PATKOI-RANGE
CHIN HILLS
ARRAKAN-YOMA
PEGU-YOMA
SHAN-PLATEAU
Chittagong
Akyab
Borongo I
Kyouk pyu
Ramri I
Cheduba I
Sandoway
Cape Negrais
Mouths of the Irrawaddy
Maingkhwan
Mogaung
Katha
Bhamo
Wuntho
Kindat
Kalewa
Kabwet
Mandalay
Pakokko
Yenangyat
Singu
Yenangyaung
Minbu
Padoukbin
Banbyin
Prome
Rangoon
Gulf of Martaban
Moulmain
INDEX OF COLOURS
Pliocene (Irrawaddi division)
Miocene (Pegu division)
Upper Eocene (Nummulitic)
Upper Cretaceous and Lower Eocene (Chin Shales)
Metamorphic and pre-tertiary rocks
94°
98°
24°
20°
16°

The Development and Sub-division of the Tertiary system in Burma, by DR. FRITZ NOETLING, F.G.S., *Palæontologist, Geological Survey of India.* (With a map).

HISTORICAL SUMMARY.

In the following summary of the former geological work done in Burma, I shall restrict myself to a review of those papers which deal with Lower and Upper Burma, that is to say with that part of Further India which is situated between the Shan hills in the east and the Arrakan Yoma in the west, and which represents, properly speaking, the country of Burma. I shall therefore disregard all papers dealing with the geology of Tenasserim and Arrakan.

Although, since the end of the last century, Burma has been visited by numerous travellers, who have related their experiences in various publications, the outcome of these travels has been very poor, with regard to the geological knowledge of the country. This is the more remarkable in that Burma has been famous for its mineral wealth, and nearly every traveller had in view the enormous mineral resources of the country. The meagre results are doubtless due to the want of geological training of most of the travellers, and this in its turn might again account for the legend of the enormous mineral wealth of Burma.

Among the names of those who wrote on geological subjects connected with Burma, previous to the researches of Dr. Blanford, Mr. Fedden, and Mr. Theobald, two only deserve mention, but they shine with the greater brilliancy amongst the numerous amateur attempts to deal with the geology of Burma: these are the names of Dr. Buckland and Dr. Oldham.

As early as 1829, from specimens which had been collected by Mr. Crawford in Upper Burma, and brought by him to England, Dr. Buckland recognised the following formations:—[1]

1. Alluvium.
2. Diluvium.
3. Fresh-water marl.
4. London-clay and calcaire grossier.
5. Plastic clay with its sands and gravel.
6. Transition limestone.
7. Grauwacke.
8. Primitive rocks, marble, mica slate.

Considering the state of geological science at that period, it is astonishing how accurately Dr. Buckland has recognized the formations which occur in Burma. It is unnecessary here to deal with his groups 6 and 8, as, for the purposes of this paper, we are mainly interested in the younger formations; but, with regard to these, it must be said that Dr. Buckland has already recognized some of the most important sub-divisions of the Burma tertiaries. Had he not been led by a mistaken inference to suppose that the fossil bones were also found in diluvial beds in Burma, he would, in fact, already have fixed the great divisions into which the tertiary rocks of Burma can be divided. If we substitute "Upper Tertiary" for the word "Diluvium," or if we keep in mind the fact that his diluvium really represents tertiary strata, we shall see that Dr. Buckland has already sketched in

[1] Transact. Geolog. Soc., 2nd series, 1829, vol. ii, p. 377.

broad outlines the sub-division of a part of the tertiary system in Burma, which still holds good at the present day. His diluvium and fresh-water marl represent the two groups into which I have divided the Burma strata, *viz.*, the upper ossiferous Irrawaddi division and the Yenangyoung division; the "London clay" represents the Pegu division, as is unmistakeably proved by the list of fossils, and if we unite his group No. 5 with the London clay, the three upper divisions of the Burma tertiaries are at once recognized.

That the nummulitic formation was overlooked is easily explained, when we remember that its outcrops are only visible far away inland at places that Mr. Crawford could not visit.

Dr. Buckland however, was, mistaken in identifying a piece of rock from Minlindoung near Yenangyoung with the "Grauwacke" formation of Europe, as, no such strata occur within the neighbourhood of Yenangyoung, particularly at the said hill, which is entirely built up of tertiary strata.

It is much to be regretted that no opportunity for the study of the geological formations of Burma was afforded to Dr. Oldham, beyond those casual visits ashore, when the necessary delays of a river journey in those days stopped the progress of the mission to Ava. Otherwise that acute and careful observer would have been able to give us a more detailed account of the geology of Burma, than that to be found in his notes on the "Geological features of the banks of the Irrawaddi, etc."[1] As it is, Dr. Oldham was obliged to give his observations in the form of a narrative, which, although full of lucid and detailed observations, renders it very difficult to follow the author's opinion as to the division of the groups he has noticed. Dr. Oldham expresses his opinion that the rocks of the area within which the oilfields of Yenangyoung are situated belong to the tertiary system, but probably owing to lack of time he does not go into the subject of the division or correlation of these tertiary beds.

It was not until after the researches of Dr. Blandford, Mr. Fedden and Mr. Theobald in Lower Burma, that anything like a sub-division of the tertiary system was attempted. Mr. Theobald, who has embodied the results of his own researches and those of his two colleagues in his interesting memoir on the Geology of Pegu,[2] proposes the following sub-division for the Tertiary rocks of Lower Burma:—

Younger Tertiary	Fossilwood group. Pegu group.
Older Tertiary .	Nummulitic group.

Of these the Nummulitic group is considered as correlative with the Eocene of Europe, while the Pegu group represents the Miocene; the "Fossil wood group" represents the Pliocene, but Mr. Theobald leaves it an open question as to whether strata of probably Post-Pliocene age are not perhaps also represented in the "Fossil wood group."

We shall presently see that Mr. Theobald has quite correctly recognized the principal divisions of the tertiary rocks in Burma, and although he may have failed in the accurate delimitation of these groups, it is well to state at once that these three sub-divisions are also recognizable in Upper Burma. Where Mr. Theobald's division is chiefly defective is with regard to the Lower Tertiary. Subsequent researches have proved that the "Axial group" (which Mr. Theobald has, on the

[1] Yule: Narrative of a mission to the Court of Ava in 1855. Appendix A, *p.* 307.

[2] Memoirs of the Geological Survey of India, Vol. X.

strength of a misinterpreted fossil, regarded as of Triassic age) must either be included in the tertiary system, of which it represents the lowest division; or might probably form the highest beds of the cretaceous system. Now, anyone acquainted with the country in which the "Axial" formation is chiefly developed, will readily understand the difficulty of accurate observation in such a jungly country as the Arrakan Yoma. In fact, the question of the age of the "Axial group" is not quite settled yet. All we know is that it does not belong to the Triassic system: this may be considered as certain, but whether it represents the lowest tertiary or the topmost cretaceous strata, is a question which still requires careful investigation. In the following pages I have provisionally accepted the view of the tertiary age of the "Axial group," but I wish to state at once that by no means do I consider this question as decided.

The same applies to Mr. Theobald's Negrais rocks, which are probably only metamorphosed Eocene beds. But not having seen these beds I am unable to express my views as to their appearance.

Mr. Theobald has sub-divided both the Pegu and the Fossil wood groups, the first into two, the second into three sub-divisions; but none of these can, to judge from our present experience, claim more than a local importance.

In the following division of the Tertiary rocks in Burma, I have attempted to combine Mr. Theobald's observations with my own in Upper Burma, and I trust that I may have at least succeeded in fixing the outlines of groups therein represented. But years and years of patient labour will elapse before we can arrive at anything like a definite idea of the finer details. If in the following pages the Upper Tertiary is more explicitly dealt with, this is not because it is of much more importance than the Lower Tertiary, but because my work brought me chiefly in touch with the Upper Tertiary.

DIVISION OF THE TERTIARY ROCKS OF UPPER BURMA.

Wherever a complete series of the tertiary beds is developed in Upper Burma, we can, with the greatest ease, recognize and distinguish two groups, which differ widely in the character of the fauna they contain.

The lower group is characterised by a *marine* fauna, which is entirely free from any terrestrial or fluviatile elements in the lower part, but locally shows a slight foreign element by the admixture of rolled fragments of terrestrial animals in its upper beds.

The upper group contains chiefly remains of *terrestrial* animals, mixed with such forms as, according to the habits of their present representatives, must have led an *aquatic* life.

Hand in hand with this wide difference in the palæontological characters goes a distinct change in the features of the sediments. Dark bluish and grey colours characterise those of the lower, and yellow, olive-green and red those of the upper group.

Notwithstanding this wide difference between the two groups, it seems as if the upper rests conformably on the lower, although there exist no passage beds between the two,—a fact which must not be overlooked. I therefore divide the Burma tertiaries into two sub-divisions, *viz*:—

2. Upper Tertiaries or Burma series.
1. Lower Tertiaries or Arrakan series.

For the lower division I suggest the name of *Arrakan series*, owing to its chief development in the Arrakan Yoma; the upper one may be called the *Burma series*, because it is chiefly developed in the broad depression between Arrakan Yoma in the west and Shan hills in the east, which forms the country of Burma proper.

I. ARRAKAN SERIES.

The Arrakan series can again be sub-divided into three groups, which palæontologically, as well as lithologically exhibit considerable differences.

The lowest of these groups is very little known; in fact, we may say we know nothing with regard to its palæontological features.

The middle group is characterised by the abundance of *Nummulites*; while the chief feature of the upper group is the total absence of this genus. Lithologically the two lower groups are characterised by shales and limestones, while, in the upper, sandstones predominate to the nearly total exclusion of other rocks. For the lowest group I suggest the name *Chin division*, while for the middle and upper one Mr. Theobald's names *Nummulitic division* and *Pegu division* may be retained.

1. THE CHIN DIVISION.

Only the bare outlines of the features of this group can be laid down up to the present, it being one of the least known members of the Burma tertiaries. I am nearly certain that subsequent discoveries will essentially modify the views here expressed. So far as I am able to say for the present, the following are the features of this group.

Lithologically, flysch-like shales, and hard limestones are the predominating rocks. It seems as if the shales almost exclusively occupied the lower part of the group, and were followed by the limestones.

Not even the approximate thickness of the shales can be given, but it may safely be supposed that it was considerable. So far as it is known, the central part of the Arrakan Yoma is chiefly built up of these shales, where they form, particularly in the Chin country, numerous parallel ridges rising to over 7,000 feet above sea level. No fossils have been discovered for the present in these shales, but this by no means proves that they are unfossiliferous.

Mr. Theobald's so-called "Axial group" of the southern part of the Arrakan Yoma, which he considered of Triassic age, represents in a broad sense these shales, and it is chiefly due to the observations of Mr. Griesbach, who examined a part of the Arrakan Yoma, where the Axial group was supposed to be present, that we know that it belongs to the tertiary system, and probably forms its lowest part. It requires, however, a long and careful examination before more can be said about the Chin-shales, an examination which will be extremely difficult in a country like the Arrakan Yoma, which is covered with almost impenetrable virgin forest.

2. THE NUMMULITIC DIVISION.

We know a little more about the middle part of the Arrakan series, although this knowledge is very scanty. According to Mr. Theobald, the total thickness of the *Nummulitic* or *Eocene group*, as he calls this subdivision, is 1,223 feet, but to judge from the table given on page 100 of his Memoir, it is quite certain that he has included

at least 227 feet more, probably about 500 feet of shales, which probably should be included in the Chin shales. However, this is a matter which can only be decided by actual observation in the field.

According to Mr. Theobald, the lower part of the nummulitic division consists of shales and sandstones, occasionally fossiliferous, capped by a bed of highly fossiliferous nummulitic limestone, of only 10 feet in thickness.

Although I have no doubt as to the correctness of this observation, it is quite certain that in a northern direction the limestone increases in thickness and importance, at the expense of the arenaceous beds. However, this is a matter which must be left to the future to decide.

The fauna discovered in this group, for which we may for the present retain the name *Nummulitic* division, is a rich one, but we know absolutely nothing as to its relationship, because owing to more pressing work, none of my predecessors have undertaken the task of studying it. All that we know at present is that it contains numerous species of the genus *Nummulites*, and, in a bed which most probably belongs to the upper part of the series, the well-known Eocene species, *Velates schmideliana*, Chem. sp. As I have pointed out in the paper, in which I described the occurrence of this species, [1] we may infer from the limited vertical distribution of this species, not only in Europe, but also in Western India, that the stratum in which it was found in Burma belongs to the Eocene system, and must most probably be considered as correlative to the Khirthar group of Western India.

The occurrence of the genus *Nummulites* together with the typical Eocene species, *Velates schmideliana*, Chemn. sp., leaves, therefore, not the slightest doubt that this part of the Arrakan series must be considered as of Eocene age, having in the Khirthar group its correlative in Western India. The lower Tertiaries would therefore be subdivided as follows:—

1. Upper Eocene: *Nummulitic* division.
   Shales and limestones containing a rich fauna of typical eocene forms,
2. Lower Eocene (?): *Chin shales.*
   Shales predominate and have not yielded any fossils up to the present time.

As regards the distribution of the two sub-divisions of the Eocene rocks in Burma it is practically such that the Chin-shales cover a much wider area than the nummulitic division, which, so far as our present knowledge goes, forms only a comparatively narrow band along the outskirts of the Arrakan Yoma.

In conclusion, however, I wish particularly to point out that all that I have said above regarding the subdivision of the Lower Arrakan series must be considered as preliminary. I myself have only very rarely had occasion to observe it, and the above remarks are chiefly based on Mr. Theobald's observations, as they appear in the light of the later researches, particularly those by Mr. Griesbach and myself. I need hardly add that it will require years and years of careful labour in the field, as well as in the museum, before we arrive at anything like a clear conception of the development of the Eocene rocks in Burma.

3. THE PEGU DIVISION.

The name "Pegu group" was proposed by Mr. Theobald "for a very important

[1] Records, Geological Survey of India, 1894, vol. xxvii, page 103.

series of beds intervening between the Eocene or nummulitic division on the one hand, and the fossil wood division on the other."

The above definition of the Pegu division would be a very clear and concise one, if Mr. Theobald had more accurately defined the lower boundary of his "fossil wood group." As it is, the boundaries of the "fossil wood group" are very uncertain and thus the upper limit of the Pegu division is very ill-defined.

I propose to apply the name of Pegu division to that series of beds, which are between the Eocene rocks—characterised by their peculiar marine fauna—and the Irrawaddi division—characterised by its peculiar terrestrial fauna.

In the above definition, the Pegu division constitutes a very well circumscribed series of beds, which are characterised as follows :—

The fauna is of a marine type throughout, but the genus Nummulites is entirely absent. Towards the upper limit rolled fragments of terrestrial animals are, in one place at least, mixed with a purely marine fauna; lithologically, sandstones of pepper and salt colour are predominant, while blue clays are more subordinate.

The above features are so well defined wherever the Pegu-division occurs in Upper Burma, that it is not easy to mistake it, although it varies locally a good deal, as may be expected in a series chiefly composed of sandstones and clays; so that it is frequently very difficult to correlate the local developments of the Pegu division at different localities in Burma. In fact the local developments differ so widely that even at places close to each other, such as Minbu, Yenangyoung, Yenangyat it is extremely difficult, if not impossible, to correlate the single strata composing the sections at the different localities. The difficulty increases of course with the distance, and years will lapse before the relations of this division in Lower and Upper Burma are sufficiently studied. We know, however, for the present enough of the development of this group to enable us to give some more details. The Pegu division may be conveniently separated into two sub-divisions, for the lower of which I propose the name of *Prome stage* owing to its chief development in the neighbourhood of that town, while for the upper one the name of *Yenangyoung stage* is suggested.

A.—Prome Stage.

a. Thickness.

Mr. Theobald describes a section of this stage near Prome, measuring 1,950 feet in thickness; but he adds that this apparently does not represent the total thickness. Although, if I interpret his views correctly, he does not think that the total thickness is very much greater.

At Yenangyoung the drill has gone through rocks of the Prome stage up to a depth of 1,000 feet without apparently touching their base.

At Yenangyat it is known partly by surface outcrops, partly by borings, to have a thickness of not less than 1,100 feet.

On the right bank of the Chindwin between the Kale and Yu river, I estimated its thickness at about 5,100 feet. In this part of the country I must have been pretty close to the base, although the actual contact between the upper Eocene and the lower beds of the Prome stage was not observed, but numerous pebbles containing Eocene fossils indicated the proximity of the Eocene beds.

If therefore we estimate the total thickness of the Prome stage at something like 5,000 feet, I think we shall not be very far off the mark

b. Lithological characters.

The chief constituents of the Prome stage are sandstones and clays, the latter are however much subordinate to the former; still more subordinate are coal seams and ferruginous clays ; locally the sandstones contain petroleum, and, at isolated places, the fossil resin, burmite. The sandstone is very uniform in character, it is finely grained, of a greyish colour, which may best be styled "pepper and salt colour." Sometimes the sandstone is very soft, other beds are more siliceous, and therefore harder. When exposed, these beds disintegrate into rather regular lumps, which retain for a long time their original position, before they fall to pieces. Such beds which resemble the pavement, may frequently be seen between Thayetmyo and Prome, or on the Upper Chindwin.

The clay is also of very uniform character, being generally a very tough clunch of bluish colour.

Sandstone and clay alternate in beds of various thickness; frequently, as for instance near Yenangyoung, beds of clay as thin as paper may alternate with similar beds of sandstone, while at other places, as for instance in the Upper Chindwin district, the sandstone forms a continuous bed of several hundred feet in thickness. The clay beds may also attain a considerable thickness, but I never found that they equalled the sandstone in this respect.

The coal seams are generally of small thickness, the thickest known to me is a seam of 10 feet, cropping out in the ravine of the Nantahinchoung in the Upper Chindwin district; generally they are between 1 and 2 feet in thickness. It would exceed the limits of this paper were I to dwell in detail on the occurence of the coal in Upper and Lower Burma; those interested in its occurence will find ample information in the papers cited below.[1]

It seems, however, that in the Chindwin district the coal seams are restricted to the lower part of the Prome stage, but to judge from other localities such as Kabwet, Wuntho or Thayetmyo some seams of inferior quality also occur in the upper parts.

As the occurrence of the petroleum will be dealt with in a special memoir, which will shortly be published, it is needless to go into details. All that may be said is, that it appears that the petroleum chiefly occurs in the upper parts of the Prome

[1] Oldham: Memorandum on the coal found near Thayetmyo on the Irrawaddi river, Selections from the Records of the Government of India, Home Department No. X, page 99, 1856. Reprinted in papers on Burma, issued by the Geological Survey.

Oldham, in Yule's Narrative of a Mission to the Court of Ava, Appendix A., page 330.

Jones: Notes on Upper Burma: Records of the Geological Survey of India, Vol. XX, Part II, 1887, page 185.

Noetling: Memoir on the Upper Chindwin Coal-fields, 1889.

Noetling: Report on the coal-fields in the Northern Shan States: Records of the Geological Survey of India, 1891, Vol. XXIV, page 99.

Noetling: Note on the Geology of Wuntho in Upper Burma: Records, Geological Survey of India, Vol. XXVII, page 119.

stage, but that it is unquestionable that small quantities are also found in the lower parts.

The occurrence of the fossil resin, burmite, the famous amber of Burma, has been described by me in a special paper.[1] Dr. Helm[2] has devoted two papers to the chemical properties of this fossil resin, which, according to him, is distinctly different from the real amber or succinite.[3]

c. Palæontological characters.

Although the rich fauna which Messrs. Theobald and Fedden collected in the Pegu division of Lower Burma still waits to be described, the examination of the fauna discovered in the petroleum-bearing strata of Yenangyat has shed so much light on the age of the Prome stage that we can now classify it definitely in the sequence of the tertiary beds without being obliged to have recourse to an indirect method. The information recently obtained by the deep borings at Yenangyat, has proved that the fauna which I have described[4] from this place comes from the petroliferous sandstone at the top of the Prome stage. The following species have been observed:—

1. *Paracyathus caeruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.
3. *Ostrea sp*
4. *Pecten cf. favrei*, d'Arch & Haime.
5. *Daphoderma cælata*, Reeve.
6. *Nucula alcocki* Noetling.
7. *Astarte* (?) *dubia*, Noetling.
8. *Venus cf. scalaris*, Bronn.
9. *Tellina* (*Tellinella*) *hilli*, Noetling.
10. *Tellina kingi*, Noetling.
11. *Solen sp.*
12. *Corbula harpa*, d'Arch. & Haime.[5]

[1] On the occurrence of Burmite in Upper Burma: Records, Geological Survey of India, 1893, vol. xxvi, page 31.

[2] Note on a new fossil amber-like resin occurring in Burma: Records, Geological Survey of India, 1892, vol. xxv, page 180

Further Note on Burmite, a new amber-like fossil resin from Upper Burma, Records, Geological Survey of India, 1893, vol. xxvi, page 61.

[3] It may here not be quite out of place to correct a mistake with regard to the age of certain coal seams occurring in Tenasserim. Mr. Oldham in the Manual of India, 2nd edition, page 297, expresses his view, that as the coal contains small nodules of a resinous mineral like amber, these coal seams were of cretaceous age, because in the Assam hills the mineral resin is characteristic of the cretaceous coals. If any inference regarding the age were admissible from the association of fossil resin and coal, it could only be one, and that is that the coal seams are of miocene age, because everywhere in Upper Burma the fossil resin is found in strata belonging to the Prome stage, which is of distinctly miocene age.

[4] Memoirs, Geological Survey of India, vol. XVII, Part I.

[5] It may be remarked here that the species which I determined as *Corbula harpa* d'Archiac and Haime is really different from that species, although this could not be recognised at the time owing to the rather deficient figure of Messrs. d'Archiac and Haime. The recent examination of the *Corbula harpa* d'Arch. and Haime from Sind has proved that notwithstanding the great similarity of the right valve, it materially differs from the Burma species by the sculpture of the left valve; *Corbula harpa* d'Arch. and Haime from Burma must therefore be cancelled, and a new name substituted for it. My remarks on page 4 of the abovenamed memoir, have therefore been fully borne out by the facts, and one anomaly of the otherwise truly miocene fauna has disappeared.

13. *Trochus buddha*, Noetling.
14. *Trochus blanfordi*, Noetling.
15. *Solarium affine* Sow.
16. *Discohelix minuta*, Noetling.
17. *Turritella affinis*, d'Arch. & Haime.
18. *Siliquaria sp.*
19. *Calyptraea rugosa*, Noetling.
20. *Natica obscura*, Sow.
21. *Natica callosa*, Sow.
22. *Sigaretus cf. bicostatus*, Sow.
23. *Aporrhais* sp.
24. *Cypræa granti*, d'Arch. & Haime.
25. *Trivia smithi*, K. Martin.
26. *Cassidaria dubia*, Noetling.
27. *Cassidaria minbuensis*, Noetling.
28. *Ficula theobaldi*, Noetling.
29. *Triton pardalis*, Noetling.
30. *Ranella tubercularis*, Lamark.
31. *Nassa cautleyi*, d'Arch & Haime.
32. *Clavella djocdjocartæ*, K. Martin.
33. *Fasciolaria nodoulsa*, Sowerby
34 *Fasciolaria feddeni*, Noetling.
35. *Murex (Muricidea)* sp.
36 *Murex tschihatscheffi*, d'Arch & Haime.
37. *Murex arrakanensis*. Noetling.
38. *Voluta dentata*, Sowerby.
39. *Oliva djocdjocartæ* K. Martin.
40. *Cancellaria cancellata*, Lam.
41. *Rapana* sp.
42. *Terebra fuscata*, Brocchi.
43. *Pleurotoma (Drillia) interrupta*, Lamark.
44. *Pleurotoma yenanensis*, Noetling.
45. *Conus (Rhizoconus) mallacanus*, Hwass.
46. *Conus (Leptoconus) marginatus*, Sowerby.
47. *Balanus sublaevis*, Sowerby.
48. *Callianassa* sp.
49. *Pagurus* sp.
50. *Lamna* sp.
51. *Galeocerdo* sp.
52. *Carcharias (Prionodon)* sp.

Out of a total of 52 species, 48 were specifically determined, but among these there are three species which could only be, with some doubt, referred to previously known species. There remain therefore 38 species, which are sufficiently well determined to allow of geological conclusions being drawn from them. Out of these 38 species, 15 have been recognized as new, while the balance of 23 species could be identified with species previously described, but as the species referred to *Corbula harpa*, from western India, cannot be considered as identical with this species, the figures therefore now stand as follows :—

New species . . .	16
Previously described species	22

The geological distribution of these 22 species is as follows :—

Recent, but not previously known in fossil state.

1. *Paracyathus cæruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.

Nari group—

1. *Daphoderma cælata*, Reeve (*Arca burnesi*, d'Arch, and Haime).
2. *Solarium affine*, Sowerby.
3. *Turritella affinis*, Sow.
4. *Cypræa granti*, d'Arch. & Haime.
5. *Voluta dentata*, Sowerby.

Gaj group—

1. *Daphoderma cælata*, Reeve (*Arca burnesi*, d'Arch. & Haime).
2. *Natica obscura*, Sow.
3. *Nassa cautleyi*, d'Arch. & Haime.
4. *Balanus sublævis*, Sow.

Older Tertiary—

1. *Daphoderma cælata*, Reeve.
2. *Fasciolaria nodulosa* Sowerby.

Of uncertain horizon are—

1. *Natica callosa*, Sowerby.
2. *Murex tschihatscheffi*, d'Arch. & Haime.
3. *Conus* (*Leptoconus*) *marginatus*, Sow.

In the Miocene of Java have been found—

1. *Trivia smithi*, K. Martin.
2. *Clavella djocdjocartæ*, K. Martin.
3. *Oliva djocdjocartæ*, K. Martin.
4. *Cancellaria cancellata*, Lam.
5. *Pleurotoma interrupta*, Lam.
6. *Conus* (*Rhizoconus*) *mallacanus*, Hwass.

From the above list it is evident that the fauna cannot be older than of Miocene age : only two species could be identified, which occur in the older tertiary beds of India : one of these, however, also ascends into higher groups, in fact, it is still living in the Indian Ocean. The geological horizon of three species is unknown, and we may therefore disregard them for the moment. Out of the remaining species—

Two are recent and not previously known in a fossil state.
Five range from the Miocene to the present day.
Three have been found in the Miocene of Java.
Four have been found in the Nari group of Western India.
Three have been found in the Gaj group of Western India.

As out of a total of 17 species, 7, that is to say nearly 50% are still living, we are therefore justified in assuming a miocene age for the beds which have yielded this fauna. It only remains to be seen whether the fauna bears a greater resemblance to the Gaj or to the Nari group of Western India. The evidence in this regard is very meagre, in fact it would be rather rash to form a final conclusion, but from the fact that the species from Java have been found in beds which are considered as of the same age as the Gaj group, I feel inclined to consider the fauna of the Prome stage as correlative to the Gaj group of Western India.

d. Facial development of the Prome stage.

In studying the development of this stage, particularly in Upper Burma, it is at once obvious that, notwithstanding the purely marine character of the fauna, some beds, which must be considered as homotaxial to the former, were either deposited in estuaries or at no great distance from the coast.

For instance, at Yenangyoung, a well, which had reached a depth of 156 feet from the surface, and which had, in the light of the information recently obtained, passed through the 1st and 2nd petroliferous sands, a highly fossiliferous conglomerate of about 6 inches in thickness was discovered in which I collected the following species :—

1. *Corallium, gen. div*; one closely related to *Paracyathus cæruleus, Dunc.*
2. *Teredo* sp.
3. *Venus* sp.
4. *Cardium* sp.
5. *Arca* sp.
6. *Pecten* cf. *favrei*, d'Arch & Haime.
7. *Gastropoda, gen. div.*

The invertebrata are all very ill-preserved, in fact they are either only casts or moulds, the calcareous substance of the shell being entirely destroyed by sulphuric acid, which is represented by a large quantity of iron pyrites. The latter makes the preservation of these fossils almost impossible: notwithstanding repeated coatings of varnish, they have, in the damp climate of Calcutta, almost entirely crumbled to pieces with considerable efflorescence. The vertebrata have yielded the following list :—

1. *Teleostei* gen. div.
2. *Myliobatis* sp.
3. *Odontaspis* sp.
4. *Carcharias* sp.
5. *Chelonian* bones.
6. *Crocodilis* sp.
7. *Antelope* sp. (?)
8. *Anthracotherium silistrense.*
9. *Rhinoceros* or *Hippopotamus* sp.

Besides the abovenamed forms which could be recognized with certainty, the conglomerate contained numerous fragments of bones, which have been too much rolled to be determined. The chief interest however rests with the fact, that fragments of terrestrial and estuarine forms are mixed with a purely marine fauna, and that such a strangely composed fauna has been found in strata between the 2nd and 3rd oil-sand at Yenangyoung.

On the other hand, the petroliferous sand of Yenangyat, which is perhaps a little higher in the series, has yielded the purely marine fauna above described.

In the Upper Chindwin district the coal-seams in the lower part of the Pegu division apparently indicate an estuarine, or at least a littoral deposit, while further south near Thayetmyo, a purely marine fauna is found in the lower portion of the Prome stage. It seems to me, therefore, that not only are beds, which are undoubtedly homotaxial, partly marine and partly of littoral or of estuarine character, but that also owing to local oscillations these changes take place in a vertical direction. On the whole it may, however, be said that the marine character is more pronounced

in Lower Burma, while the littoral or estuarine formation prevails in Upper Burma. This view, however, by no means affects the opinion expressed above as to the wide difference between the fauna of the Prome stage and that of the Irrawaddi division, nor does it modify the conclusions based thereon with regard to the sub-division of the Burma tertiaries.

e. Sub-division of the Prome stage.

It is obvious that, under the circumstances above described, a general sub-division of the Prome stage is extremely difficult, and that those attempts, which have so far been made by Mr. Theobald in Lower Burma, and by myself in the Upper Chindwin district are of purely local value, hardly holding good for more than a few miles around the locality for which they were made.

Under these circumstances it would be superfluous to repeat them here. All that can be said is that, perhaps, after years of careful study, and after an exhaustive examination of the fauna, and a most careful determination of the fossiliferous horizons in the sequence of the series, it will, perhaps, be possible to arrive at a general sub-division of the Prome stage; for the present we must be satisfied with local sub-divisions, without making any attempt at correlating their individual members.

B.—THE YENANGYOUNG STAGE.

A marked lithological difference distinguishes the overlying series of beds from the Prome stage. No sharper boundary can be imagined than the contrast between the bluish tinges of the Prome stage, and the brown or olive-coloured beds of the Yenangyoung stage at places where the contact between the two is well exposed, as for instance in the Oung-Ban ravine between Kodoung and Twingon. In fact, the results of the deep borings carried out at Twingon render it utterly impossible to assume an absolutely conformable superposition of the Yenangyoung stage on the Prome stage. The study of these sections leads to the assumption that a break must exist between the Upper Prome beds and the lower beds of the Yenangyoung stage, at least in the country near Yenangyoung. On the other hand it deserves to be mentioned that at Yenangyat the Yenangyoung beds rest (apparently with absolute conformity) on the Prome stage.

Although there exists, therefore, a sharp lithological difference between the Prome stage and the Yenangyoung stage—a difference from which one would rather feel inclined to consider the latter as the basal beds of the Irrawaddi division, so great is the lithological similarity between the two—still the palæontological evidence unquestionably proves that the Yenangyoung stage is widely different from the Irrawaddi division and closely related to the Prome stage. It must therefore be included in one series with it.

a. Thickness.

At Yenangyoung the beds composing the Yenangyoung stage form a series of about 1,100 feet in thickness.

At Singu the thickness is about 700 feet, but here the whole series is not completely exposed, and it is impossible to say to what depth it may still extend.

At Yenangyat the whole series is again well seen: its thickness at this place is about 1,200 feet.

It is therefore tolerably certain that, at least in Central Burma, the Yenangyoung stage is only of moderate thickness as compared with the other groups composing the Burma tertiaries.

b. Lithological characters.

The chief constituents of the Yenangyoung stage are soft clays, alternating with beds of sandstone, which may either form thin hard bands, or thicker soft beds. The clay is usually of olive colour, but in various instances, bluish tinges, particularly near Yenangyat, have been observed. One involuntarily imagines a struggle between the bluish colour of the older beds and the olive colour of the newer strata; there are frequent relapses, so to speak, to the original bluish colour, till eventually the olive colour gets the upper hand and bluish tinges have entirely disappeared in the Irrawaddi division. This struggle between the two colours is extremely well seen at Yenangyat, where, after having made a final effort, the bluish colour of the clay disappears with the highest bed of the Yenangyoung stage. The sandstone is usually very friable, and of a yellowish colour; bands of hard kidney-shaped or globular concretions occurring very frequently.

A most remarkable feature is the presence of gypsum, which occurs frequently in large crystals in the clayey beds. It is noticeable that no gypsum is found either in the lower Prome stage or in the Upper Irrawaddi division, and in this respect its occurrence forms an exceedingly useful feature for the recognition of the Yenangyoung stage. One may be almost certain to have beds of the Yenangyoung stage under observation when the gypsum is noticed.

c. Palæontological characters.

Fossils are rather scarce in the Yenangoung stage, that is to say, the localities in which they are found are not numerous; but when present the fauna is usually a rich one. So far I have discovered three places where fossils have been found, and every one of these localities unquestionably represents a different horizon.

The lowest horizon is probably represented by beds which contain a very rich fauna near Minbu. In a similar horizion, fossils also occur at Yenangyat, but I never found at this place a bed where they were recognizable, being in every case mostly fragments.

Next in the series follows the *Cypricardia* bed of Singu.

The last in the series is the *Batissa* or *Cyrena* bed containing countless numbers of the two species *Batissa* (*Cyrena*) *crawfurdi* and *petrolei.* It will be useful to discuss the palæontological characters of each of these beds separately, and eventually compare the whole of the fauna with that of the Prome stage.

1. MINBU-BED.

The fauna of this bed, which is well exposed at the hill, north of the mud-volcanoes, has been described by me in the memoir previously quoted. So far the following species have been found:—

1. *Paracyathus cæruleus*, Duncan.
2. *Ostrea*, sp. 1.

3. *Pecten* cf. *favrei*, d'Arch. & Haime.
4. *Nucula alcocki*, Noetling.
5. *Venus* sp.
6. *Tellina kingi*, Noetling.
7. *Corbula* spec. nov.[1]
8. *Trochus buddha*, Noetling.
9. *Trochus blanfordi*, Noetling.
10. *Solarium affine*, Sowerby.
11. *Solarium cyclostomum*, Menke.
12. *Scalaria birmanica*, Noetling.
13. *Scalaria irregularis*, Noetling.
14. *Scalaria subtenuilamella*, d'Arch. & Haime.
15. *Turritella affinis*, d'Arch. & Haime.
16. *Calyptræa rugosa*, Noetling.
17. *Natica obscura*, Sowerby.
18. *Natica callosa*, Sowerby.
19. *Cerithium* sp.
20. *Strombus nodosus*, Sowerby.
21. *Cypræa granti*, d' Arch. and Haime.
22. *Cassis d' archiaci*, Noetling.
23. *Cassidaria dubia*, Noetling.
24. *Cassidaria minbuensis*, Noetling.
25. *Triton* (*Simpulum*) *davidsoni*, d'Arch. & Haime.
26. *Triton pardalis*, Noetling.
27. *Ranella tubercularis*, Lamark.
28. *Nassa cautleyi*, d' Arch. & Haime.
29. *Clavella djocdjocartæ*, K. Martin.
30. *Fasciolaria nodulosa*, Sowerby.
31. *Murex arrakanensis*, Noetling.
32. *Volvaria birmanica*, Noetling.
33. *Voluta dentata*, Sowerby.
34. *Oliva djocdjocartæ*, Martin.
35. *Terebra fuscata*, Brocchi.
36. *Pleurotoma voyesi*, d'Arch. & Haime.
37. *Pleurotoma* (*Drillia*) *interrupta*, Lamark.
38. *Pleurotoma yenanensis*, Noetling.
39. *Conus* (*Rhizoconus*) *mallucanus*, Hwass.
40. *Balanus sublaevis*, Sowerby.
41. *Callianassa* sp.
42. *Lamna* sp.
43. *Myliobates* sp.
44. *Carcharias* (*Prionodon*) sp.

The above list shows that the Minbu bed contains nearly the same number of species as the Prome beds and that out of a total of 44 species it contains 29 species which are common to both faunas. So far the forms peculiar to the Minbu bed are the following :—

1. *Ostrea* sp. 1.
2. *Venus* sp.
3. *Solarium cylostomum*, Menke.
4. *Scalaria birmanica*, Noetling.
5. ,, *irregularis*, Noetling.
6. ,, *subtenuilamella*, d' Arch. & Haime.

[1] Described as *Corbula harpa*, d'Arch. & Haime.

7. *Cerithium* sp.
8. *Strombus nodosus*, Sowerby.
9. *Cassis d'archiaci*, Noetling.
10. *Triton (Simpulum) davidsoni*, d'Arch. & Haime.
11. *Triton pardalis*, Noetling.
12. *Volvaria birmanica*, Noetling.
13. *Terebra fuscata*, Brocchi.
14. *Pleurotoma voyesi*, d' Arch. & Haime.
15. *Myliobates*, sp.

Of these 15 species 4 have been only generally determined, 4 are new forms and the remainder of 5 species have been previously described. Of these the following three species are found in the Gaj group:—

Scalaria subtenuilamella, d'Arch. & Haime.
Strombus nodosus, Sowerby.
Triton (Simpulum) davidsoni, d'Arch. & Haime.

in the Nari group occur—

Solarium cyclostomum, Menke.
Triton davidsoni, d' Arch. & Haime.

recent is—

Sclarium affine, Menke.

of uncertain geological horizon is—

Pleurotoma voyesi, d'Arch. & Haime.

while the last one—

Terebra fuscata, Brocchi.

occurs in the Upper Miocene of Europe.

I do not think that the above meagre list is in itself sufficient to decide the question of the age of the Minbu bed; if any inference could be drawn, it would be that it shows almost a larger number of species found in the Gaj group of Western India than the Yenangyat fauna. It may, perhaps, be possible that its actual horizon is a little lower down in the series than I have here assumed, and that it ought to be included in the Prome stage, although this would not materially alter the views here promulgated regarding the position and age of the Yenangyoung stage. I have assumed from its position in the series above the petroliferous horizon, which, so far as we know for the present, seems to be a very excellent one, that it is younger than the Yenangyat fauna; but of course it is extremely difficult, owing to the monotonous development of the tertiary strata, absolutely to correlate certain beds of two localities, which are at some distance from each other.

That there exists a difference between the two faunas cannot be denied, if we look through the above list; this difference may only represent the local variation of one and the same fauna, or it may really represent a difference in the geological age of the two faunas. For the present this question must be left undecided, as our imperfect knowledge of the tertiary fauna in Burma does not allow such intricate questions as the above to be settled; but my opinion is, that the Minbu fauna holds a position at the base of the Yenangyoung stage, and I have therefore included it in the discussion of this group. Should it, however, eventually be found better to include the Minbu-bed in the Prome stage, it must not be disregarded, that it certainly occupies a higher horizon than the Yenangyat beds.

2. *Cypricardia*-BED.

The geological position of this bed is much more accurately fixed with regard to the Yenangyat bed, than that of the Minbu bed. The Yenangyoung stage has been traced from Yenangyat down to Singu, and it is quite certain that at Singu only the higher beds of the Yenangyoung stage are exposed.

The Cypricardia bed holds a position comparatively close to the upper boundary of the Yenangyoung stage, and it must therefore be decidedly younger than either the Minbu or Yenangyat fauna. It is an argillaceous sandstone containing numerous lumps of hard clay, which, strange to say, are almost in every case perfectly riddled by the borings of a *Lithodomus*. Its thickness is not more than 6 inches, but it forms a most constant horizon, which can be easily recognized at either side of the anticline. It is probably from this bed that the late Dr. Oldham obtained some fossils, when visiting Singu in 1855.[1] Unfortunately this fauna has not been carefully examined yet, because it was only during the field season 1894-95, that I discovered the *Cypricardia* bed, but still the knowledge of the species occuring in the Yenangyat and Minbu beds has enabled me to identify some of the species occurring in it, while other forms were recognised as being absent in the abovenamed beds. The entire character of the fauna of the *Cypricardia* bed is totally different from that of either the Yenangyat or Minbu beds. While in the former the *Gastropoda* predominate—out of a total of 69 species, 45 belonging to the *Gastropoda*—it is certain that in the Cypricardia bed the *Pelecypoda* predominate not only by number of species, but also by number of individuals. The commonest forms are an *Ostrea* sp., *Pecten cf. favrei* d'Arch. and Haime, and a *Cypricardia*, besides *Paracyathus cæruleus*, Duncan. It is, however, strange that, although the *Ostrea* sp. is the commonest form, not a single well-preserved specimen could be obtained. *Pecten cf. favrei*, d'Arch. and Haime, is always well-preserved like the other Pelecypoda, and I dare say that the question whether it really represents the Indian species can now be settled; next in frequency is a beautifully preserved *Cypricardia*, and an *Avicula*, and then comes the easily recognizable *Paracyathus cæruleus*, Duncan. The following is a provisional list of the fossils, which I have been able to recognize; but I wish at once to state that this list is by no means exhaustive.

1. *Paracyathus cæruleus*, Duncan, very common.
2. *Ostrea*, sp. apparently related to *Ostrea*, sp. 1, from Minbu; very common.
3. *Pecten cf. favrei*, d'Arch. and Haime, very common.
4. *Modiola*, sp. 1, rare.
5. *Modiola*, sp. 2, rare.
6. *Lithodomus* sp., very common.
7. *Avicula* sp., very common.
8. *Daphoderma caelata*, Reeve (*Arca burnesi*, d'Arch. and Haime; common).
9. *Venus*, sp. 1, the same as found at Minbu; very common.
10. *Venus*, sp. 2, rare.
11. *Tellina* (*Tellinella*) *hilli*, Noetling; rare.
12. *Tellina kingi*, Noetling; always beautifully preserved, but not common.
13. *Trochus sp., cf. blanfordi*, Noetling; common.
14. *Solarium affine*, Sow.; rare.

[1] Yule, mission to the Court of Ava, p. 27, and Appendix A, page. 319.

15. *Conus (Rhizoconus) mallacanus*, Hwass; rare.
16. *Conus (Leptoconus) marginatus*, Sowerby; rare.
17. *Callianassa* sp. nov. The hands of a gigantic *Callianassa* sp. are not very rare.

To judge from this specimen it seems that the isolated fragment of a finger which I referred to *Pagurush*[1] really belongs to this gigantic *Callianassa*. As I have remarked above, this list is by no means an exhaustive one, and a careful examination of my collection will swell its number considerably; but it may be stated at once, that almost all the forms, which have been recognized hitherto, are identical with those described from the Yenangyat and Minbu beds. On the other hand some new forms, which had hitherto not been found in either of the abovenamed beds, have been discovered; the most conspicuous among these are—

Avicula sp.
Cypricardia sp.

besides various others.[2]

The geological horizon of the *Cypricardia* bed being decidedly higher up in the series than either of the fauna abovementioned, it is almost certain that the faunistic difference noted cannot be considered as only a local variation.

3. *Batissa-(Cyrena-)* BED.

The highest position in the Yenangyoung stage is occupied by a bed which is unfossiliferous almost throughout its whole extent, but containing at two places at least in the neighbourhood of Minlindoung, countless numbers of *Batissa crawfurdi* Noetling and *Batissa petrolei* Noetling. These two forms are also found in the next higher bed, which most decidedly belongs to the Irrawaddi division, and they form the connecting link with that series of strata which contain such an entirely different fauna from that of the older tertiaries.

If the *Cytherea promensis*, a species established by Mr. Theobald, but neither described nor figured, is, as I suppose, identical with either *Batissa crawfurdi* Noetling or *Batissa petrolei*, Noetling, we are bound to assume that this form occurs far down in the tertiary series of Lower Burma. The question is an interesting one, but it can only be decided after the examination of Mr. Theobald's collections. In Upper Burma the *Batissa* bed concludes the Yenangyoung stage, and if we assume that this horizon would be the same in Lower Burma, the logical consequence would be that the Yenangyoung stage is much thicker in Lower Burma and that on the top of the *Batissa* bed there exist several fossiliferous horizons, which are not represented in Upper Burma.

These are, however, views which can only be settled by actual observation in the field, as I do not think that the examination of Mr. Theobald's collections will shed much light on this question, as the positions of the horizons in which the fossils were collected are not always known with certainty with reference to each other.

I may conclude the description of the palæontological features of the Yenangyoung stage with the remark that, to my knowledge, no fossil wood either car-

[1] Memoir, Geological Survey of India, Vol. XXVII, part. I, page 44.

[2] I hope that I shall soon be able to give an exhaustive description of this fauna which, from its geological position, has a particular interest.

bonised or silicified has been discovered in it. The absence may be accidental, but it seems significant to me that hitherto no silicified wood has been found in either group.

c. Distribution of the Yenangyoung stage.

The Yenangyoung stage being established as the series of strata intermediate between the Prome stage and the fossil wood group (Irrawaddi division) in Upper Burma, nothing can be said with regard to its distribution in Lower Burma; but it is almost certain that it is also represented in that part, although it seems that it does not form such a well circumscribed series as in Upper Burma. In fact it seems that in Lower Burma it merges more or less into the Prome stage.

In Upper Burma it is well represented near Minbu, at Yenangyoung, Singu and Yenangyat, but it must be kept in mind that the localities where it is well exposed, are comparatively speaking of limited extent, as it appears near the surface only where the conditions have been favourable; and in almost the whole of Upper Burma it remains hidden beneath the overlying Irrawaddi division.

I am not quite certain whether the Yenangyoung stage is represented in the Chindwin hills; it is most probably represented, but it does not seem to form such a conspicuous member in the series. It is, perhaps, possible that part of the sandstone beds, which to a thickness of approximately 6,000 feet overlie the Prome stage, represent the Yenangyoung stage, but with regard to this we must await the result of further examination.

II.—THE IRRAWADDI DIVISION.

The Irrawaddi division comprises, broadly speaking, Mr. Theobald's fossil wood group, and I have therefore to explain why I changed the name and substituted a new term for Mr. Theobald's designation. The chief reason is, that "Fossil wood group" is by no means an appropriate term for this series. Not only are numerous beds, particularly in the lower part of the series utterly destitute of fossil wood, but what is much more important certain post-tertiary beds abound in fossil wood. In fact, one would rather feel inclined to apply the term "fossil wood group" to some diluvial gravel beds, so full are the latter sometimes of enormous pieces of fossil wood. For this reason these post-tertiary gravels have frequently been mistaken for tertiary strata, and, in order to avoid any confusion, I preferred a different name, and have therefore chosen the name Irrawaddi division from the enormous development attained by these beds in Upper Burma in the basin of the Irrawaddi.[1]

a. Thickness.

I include in the Irrawaddi division all the beds above the Yenangyoung stage which are characterised by the remains of terrestrial and fluviatile animals but below the unconformity which separates the post-tertiary beds from those of tertiary age.

The Irrawaddi division, as thus circumscribed, exhibits a measured thickness of 4,620 feet in the neighbourhood of Yenangyoung, but it is quite certain that this does not by any means represent the total thickness of the division.

[1] In previous papers I used the term Irrawaddi sandstone to designate this group on account of the preponderance of yellow sandstones, but I think that the term Irrawaddi division would be preferable.

The cross-cut of the Irrawaddi bed between Singu and Salemyo affords an exceedingly good section of the Irrawaddi division, from its base to most probably within a short distance of its uppermost beds. The calculated thickness of the Irrawaddi division in this section would be about 20,000 feet. This will probably nearly represent its greatest thickness in Upper Burma, at least in that part of the country which chiefly interests us for the present.

In Lower Burma the Irrawaddi division is apparently much less developed than in Upper Burma. Mr. Theobald gives no figures regarding the total thickness of his "Fossil wood group" but, to judge from his figures, it cannot be anything like that attained in Upper Burma.

b. Lithological characters.

The rocks which compose the Irrawaddi division form by their light colours a most marked contrast to the dark coloured beds of the older strata. Light yellow is the prevailing colour, but dull red, brown and olive-green tinges are by no means rare, although they take only a subordinate rank.

The predominant rock is a very soft sandstone, which might perhaps better be termed "sand-rock" of light yellow colour. It forms thick beds which frequently contain nodular or kidney-shaped concretions of extremely hard siliceous sandstone. These concretions which are sometimes of considerable size, are arranged in strings, parallel to the bedding, and stick out of the surrounding softer material forming a very conspicuous feature in the landscape. Alternating with the sandstone are beds of olive-coloured soft clay, which, however, never attain the thickness of the sandy beds.

Still more subordinate, but very important from a palæontological point of view are dull red bands of a ferruginous conglomerate. Sometimes all foreign matter is so rare that these bands form regular layers of cellular iron ore, which have in former times been used for the production of iron. Their thickness changes from a few inches up to about 15 feet, but it must be mentioned that they do not as a rule seem to form continuous layers, but more or less irregular strings, which although parallel to the bedding, may suddenly die out at one place and re-appear at another. The only exception seems to be the ferruginous conglomerate at the base of the group, which forms a very continuous layer of which I shall presently have more to say.

The composition of these ferruginous conglomerates proves that they must have been formed along a beach, for they exhibit all the flotsam and jetsam which is generally gathered in such places. There are small pieces of drift-wood now changed into hydroxide of iron, small pebbles of quartz and ferruginous clay, rolled fragments of bones, all mixed up, sometimes gathered in small heaps, sometimes spread out and forming only a thin, disconnected layer. A femur of probably *Rhinoceros sp.* which I found in one of these layers affords an exceedingly good illustration regarding the conditions under which they were formed. It rested with one side on a bed of sandstone and around it, and partly over it, were heaped ferruginous clay—pebbles, etc. etc.; now that side on which the bone rested was considerably rubbed, thus indicating the result of the friction on the underlying sand, produced by the gentle rocking of the bone by the waves, while lying on the beach.

The ferruginous conglomerates afford us therefore a material help, with regard to the conditions under which the Irrawaddi division was deposited, and from this point they deserve special attention.

c. Palæontological characters.

The Irrawaddi division is undoubtedly the most interesting in the whole series of the Burma tertiaries owing to the fact that it contains numerous remains of terrestrial and fluviatile animals. It is, however, an open question whether these remains are generally distributed throughout the group, or whether they are restricted to certain localities only. It seems to me that there is no reason why they should not be found anywhere, whenever the strata of this group are exposed, but so far as my experience goes they are much more frequent at certain localities than at others.

For instance, along the river shore from Nyounghla to a few hundred yards north of Sithabwé village fossil bones are extremely common; further north they become scarce, and north of Yenangyoung I have not yet found a single specimen, although the beds developed in this part are the same as those south of Yenangyoung village. Near Pagan I have searched for miles along the bank of the Irrawaddi, where the Irrawaddi division is well exposed, without finding a single specimen.

It is further very remarkable that not only were the first fossil bones which came from Burma, and which were described by Dr. Buckland as early as 1823,[1] collected near Yenangyoung, probably at the very locality which I mentioned above, but that also the chief collection of fossil bones which was made by the members of the Mission to Ava, was found near Yenangyoung.[2] To judge from a remark made by King Mindon Min in the most interesting conversation recorded on pages 112 and 113 of Yule's Mission to Ava, "Biloos" bones[3] are very common in the Yaw country, and it is quite possible that the list which Mr. Theobald gives[4] as coming from "Ava" refers to fossils collected in the Yaw country. They certainly cannot come from Ava, as nowhere in the neighbourhood of that town do beds of the Irrawaddi division occur.

Mr. Theobald expressly states that in Lower Burma the fossil wood group is only locally mammaliferous, and if we thus take all the evidence we must believe that the fossil bones are only of frequent occurrence at certain localities, of which three are known at the present time, *viz.* :—

1. Lema, near Thayetmyo in Lower Burma.
2. Bank of the Irrawaddi between Nyounghla and Yenangyoung.
3. Yaw-country.

Of these three localities, I know only the second from personal experience; as regards the first, we have the evidence of Mr. Theobald, and as regards the third, I must say that all the probabilities are in favour of the occurrence of fossil bones, because the very strata in which they have been found near Yenangyoung are largely developed in the broad valley of the Yaw. On the other hand, I must say that this is no absolute proof, for although the Irrawaddi division is largely developed in Northern Burma, as for instance, in the Pakôkku, Upper Chindwin, Ye-u and Shewbo Districts, yet I have not found a single specimen of a fossil bone, although I repeatedly and carefully searched for them. I may have overlooked them, a possibility which I fully admit, and future researches may discover them in

[1] Transactions of the Geol. Soc., Series II, Volume II, page 377.
[2] Narrative of the Mission to the Court of Ava, 1858, page 315.
[3] Biloo, a fabulous monster.
[4] Op jam. cit., p. 07.

parts where I have looked in vain, but for the present we must content ourselves with stating that the locality in Upper Burma where fossil bones have been found in largest numbers is the country around Yenangyoung.

The seemingly erratic manner of horizontal distribution of the fossil bones might perhaps be explained if we assume that they are restricted to a certain portion of the strata of the Irrawaddi division, and that they are therefore only found at places at which that particular portion is well exposed.

The question is a difficult one to decide, and would require further observations, but if one may be allowed to draw a conclusion from the occurrence of the fossil bones around Yenangyoung it seems that they are restricted to the lower and middle parts of the Irrawaddi division, while they are extremely rare, if not entirely wanting, in the upper part, being replaced by the frequently occurring fossil wood. This supposition would explain the curious mode of occurrence near Yenangyoung the youngest strata of the Irrawaddi division being chiefly exposed along the river bank south of Nyounghla and north of Yenangyoung.

The late Dr. Oldham[1] had already observed that the fossil bones are chiefly found in the ferruginous conglomerates and "breccia or conglomerate" which he has found at Minlindoung[2] and which is considered by me as the bottom-bed of the Irrawaddi division, and distinguished as a special bone-bed, of which more will be said later on. Besides this bed, I found fossil bones at several higher horizons, and I think that I am able to recognize certain well marked horizons characterised by their vertebrate fauna; this sub-division will be discussed presently.

As regards the fauna, which has left its remains deposited in the Irrawaddi beds, the following species and genera have been noticed by various authors. The first to determine the collection made by Mr. Crawford was Dr. Buckland, who recognised the following species:— .

Mastodon latidens, Clift.
" *elephantoides*, Clift.
Hippopotamus sp.
Rhinoceros sp.
Sus sp.
Tapirus sp.
Bos sp.
Cervus sp.
Antelope sp.
Crocodilis sp. *aff. vulgaris.*
Leptorhynchus sp. (*Garialis* sp.)
Trionyx sp.
Emys sp.

The specimens collected by Dr. Oldham, of which he has given a rough list at the end of his paper, have subsequently been more accurately determined, and I suppose that the list of fossils from Ava which Mr. Theobald gives[3] refers to them. The following species and genera are enumerated :—

Mastodon latidens, Clift.
Elephas cliftii, Cautl. and Falc.
Mastodon elephantoides, Clift.

[1] Mission to Ava, page 315.
[2] Dr. Oldham spells the word Menleng.
[3] Op. jam. cit., p. 67.

Rhinoceros sp.
Equus sp.
Hippopotamus (Hexaprotodon) irravadicus, Caut. and Falc.
Merycopotamus dissimilis Caut. and Falc.
Sus sp.
Tapirus sp.
Bos sp.
Cervus sp.
Antelope sp.
Crocodilis sp.
Leptorhynchus sp.
Emys sp.
Trionyx sp.
Colossochelys sp.

Most of these have been subsequently examined and described by Mr. Lydekker in the Palæontologia Indica and a few more species added to the above list, *viz.*, *Ursus sp.*, *Mastodon sivalensis*, *Rhinoceros sp.*, *Vishnutherium irravadicum*, *Bos sp.* The following species have been collected by me in the neighbourhood of Yenangyoung:—

1. *Mastodon latidens*, Clift.
2. *Stegodon cliftii* Caut. and Falc.
3. *Acerotherium perimense*, Lyd.
4. *Rhinoceros sivalensis*, Lyd.
5. *Hippopotamus irravadicus*, Caut. and Falc.
6. *Sus titan*, Lyd.
7. *Bubalus* sp.
8. *Boselaphus* sp.
9. *Hippotherium antelopinum*.
10. *Cervus* sp.
11. *Lutra* (?) sp.
12. *Crocodilis cf. biporcatus* (?).
13. *Gavialis sp. cf. gangeticus*.
14. *Emyda palæindica*.
15. *Trionyx* sp.
16. *Colossochelys atlas*.
17. *Testudo* sp.
18. *Emys* sp.
19. *Carcharias* sp.

Besides the species above mentioned, there are still some teeth representing three or four more species, which are, however, too ill-preserved to be determined.

Now, if we compare these lists of fossils collected at three widely separated periods, their great similarity is rather striking. In fact, although I had the best opportunity of all, my collection only adds a few more species to those already known through Dr. Buckland and Mr. Lydekker; but even these do not in the least alter the character of the fauna. If we omit the rather doubtful *Equus* sp. and assume that Mr. Oldham's *Antelope* sp. is identical with *Boselaphus* sp., the fauna consists of 26 species altogether. The character of this fauna is decidedly expressed by its composition, it being almost exclusively composed of animals which led either an entirely aquatic life or dwelt in swampy marshes bordered by shady forests, and required besides large quantities of vegetable food and an abundance

of water for their welfare. Out of the 26 species above mentioned, seven are of entirely aquatic habits, *viz.*—

Crocodilis cf. biporcatus (?).
Gavialis, sp. cf. gangeticus.
Emyda palaeindica.
Trionyx sp.
Colossochelys atlas.
Emys sp.
Carcharias sp.

To these we may add two which lead a semi-aquatic life, *viz.*:—

Hippopotamus irravadicus.
Lutra sp.

Out of the remaining species we may safely suppose that—

Rhinoceros [*Aceratherium*] *perimense.*
Rhinoceros sivalensis.
Rhinoceros sp.
Bubalus sp.
Sus titan.
Tapyrus sp.
Vishnutherium irravadicum.

and most probably also—

Merycopotamus dissimilis.
Hippotherium antelopinum.

chiefly dwelt in marshy swamps, while the remainder, *viz.*:—

Mastodon latidens.
Mastodon sivalensis.
Stegodon cliftii.
Boselaphus sp.
Cervus sp.
Bos sp.
Ursus sp.
Testudo sp.

most probably lived in the shady forests bordering the marshes.

The only region, in which were all the conditions for the existence of a fauna constituted as the above, would be the low islands and estuaries of the delta of a large stream. The numerous brooks and creeks afforded ample room and nourishment for the members of the reptilian tribe as well as for the sharks, while the low islands, covered with a luxurious vegetation, were the places where the *Ungulata* and *Proboscidea* led a comfortable life.

If we now examine the homotaxial relations of this fauna, it is at once obvious that it bears the strongest resemblance to the Siwalik fauna of India. Out of 26 species, at least 11 are recognized with certainty as being identical with Siwalik forms; these are:—

1. *Mastodon latidens.*
2. *Mastodon sivalensis.*
3. *Stegodon cliftii.*
4. *Rhinoceros* (*Acerotherium*) *perimense.*
5. *Rhinoceros sivalensis.*
6. *Merycopotamus dissimilis.*

7. *Sus titan.*
8. *Hippotherium antelopinum.*
9. *Gavialis sp. cf. gangeticus.*
10. *Emyda palaeindica.*
11. *Colossochelys atlas.*

That is to say, all such forms as have been specifically determined, except those of course which are indigenous to Burma. Out of the remaining 15 species, two, *viz.*—

1. *Hippopotamus irravadicus.*
2. *Vishnutherium irravadicum.*

are indigenous to Burma, while the remaining 13 species have for the present been only generally determined.

The proportion of species identified with Siwalik forms is therefore, if we disregard the two indigenous species, about 50 per cent. of the total or much larger than Mr. Oldham supposed it to be.[1] In fact, I have not the slightest doubt that the proportion will be still greater once the fauna has been carefully studied, there being certainly among the 13 species hitherto only generally determined some which will be found identical with Siwalik forms.

On the other hand it cannot be denied that as regards the general character of the fauna of the Irrawaddi division, it exhibits some features decidedly different from the Siwalik fauna. The *Ungulata,* although being in the majority, are represented by a much smaller number than in the Siwalik fauna, but the most striking feature is the remarkable scarcity of *Carnivora* of which only two species have so far been discovered in the Irrawaddi division, which contrasts strongly with the large number of species in the Siwaliks. I am, however, not prepared to state that these differences are absolute, my opinion is rather that once the Irrawaddi division is more explored, and we know its fauna to a larger extent, the discrepancy between the total number of species on one side, and the remarkable difference of the development of the *Carnivora* in both regions will disappear, or at least become smaller.

For the present we must content ourselves with having pointed out that notwithstanding its smaller number of species the fauna of the Irrawaddi division must be considered as correlative to that of the Upper Siwaliks.[2]

Luckily in Burma we are in a much better position for ascertaining the age of the Irrawaddi division than were the Indian geologists, when fixing the age of the Siwaliks; as previously pointed out, the Irrawaddi division rests conformably on beds of miocene age. The natural conclusion is therefore that the Irrawaddi division represents the Pliocene of Europe, a supposition which is fully in accordance with the views lately promulgated by Mr. Oldham in the second edition of the Manual of the Geology of India, according to which "it is impossible to deny that the balance of evidence is in favour of a Pliocene age." In fact we might rather say that the evidence of the fauna of the Irrawaddi division is a further strong proof of the Pliocene age of the Siwaliks, for it would be impossible to assume that the Irrawaddi division was of Upper Miocene and not of Pliocene age. Such an assumption would simply mean a perversion of all facts and a negation of the natural divisions of the Tertiary rocks in Burma.

[1] Manual of the Geology of India, 2nd edition, page 341.

[2] Mr. Lydekker, when describing the fauna of the Siwaliks, never seems to have doubted this, for the specimens collected in Burma are included among his list of the Siwalik species.

Besides its fauna the Irrawaddi division is distinguished by an abundance of fossilized wood. In fact the fossilized wood has attracted the attention of travellers in Burma more than anything else with the exception perhaps of the occurrence of rubies. There is hardly a book dealing with Burma in which reference is not made to the fossil wood, and the quaintest theories have been set forth to explain its presence in such abundance. It is, however, strange to say that although quantities of it must have been brought to England since the end of the last century no scientific examination of it has hitherto been made.

The fossil wood is distributed throughout the whole of the Irrawaddi division, but I am unable to say whether there is any rule as regards its vertical distribution. Frequently enormous logs may be seen imbedded in the strata. I noticed a specimen of about 60 feet in length, east of Yenangyoung, broken into several pieces by its mere weight, but still partly imbedded in the soft sandstone. Pieces of smaller size are of course extremely common, and cart loads might be picked up in a few hours.

There are two modes of petrification, the one in which the wood fibre has been replaced by silica, the other in which it has been replaced by hydroxide of iron. The former is the common one; the latter has been only observed in a few cases of drift-wood imbedded in the ferruginous conglomerates.

The question as to how this wood became fossilized has of course occupied the attention of more than one observer, but it cannot be said that a satisfactory explanation has hitherto been given.

Mr. Theobald having observed that the fossil wood when found *in situ* never exhibits any signs of being rolled or otherwise worn away, nor gives any other indications of transport, therefore assumes that the wood could not have been in a petrified state prior to being embedded in its present position. He therefore supposes that petrification took only place after the trees had found their present resting place, an assumption which he explains by the following quaint theory. He supposes that the trunks of trees floated about till water-logged in shallow lakes, in which, on sinking, they became mineralised through the agency of springs holding silica in solution.

The logical outcome of this theory is, that wherever a single specimen of a silicified log is found *in situ*, we are bound to suppose that just underneath that very log, a spring rose, in order to petrify it, and, having done its work, disappeared without leaving behind it any other traces of its activity. The absurdity of such a theory is too evident, and no more need be said about it, but in discarding one theory one ought to be able to replace it by a more satisfactory one. I must, however, confess that in matters of this kind, which are chiefly of a chemical nature, I am unable to give a satisfactory solution. I was therefore extremely glad to find that Dr. Irving has propounded a theory regarding the origin of the silicified wood in the Pliocene of the Libyan desert [1] which might be equally well applied to the silicified wood of Burma. I cannot therefore do better than give Dr. Irving's own words, which are as follows:—

"Remarking on the silicification of wood, he wished again to emphasize the difference in the action of carbonic acid in petrological changes, according as it

[1] Quart. Journ. of the Geol. Soc., 1894, volume L., page 547.

existed as a free acid or in combination with a base, as in sodium carbonate. The extent of the "natron" deposits pointed to the supply of alkaline waters over large areas in former times, holding the mineral in solution. The reaction of such waters upon the potash felspar of the sands furnished, by the disintegration of the crystalline rocks, would not lead to the deposition of free silica (as in the ordinary process of kaolinization), because, while the potassium was taken up as a carbonate and carried away, the silica was also removed in solution, through combination with the sodium, to form sodium silicate. This last-named salt in solution would be readily decomposed by the organic acids and the carbonic acid furnished by decaying vegetable tissue, the silica being then deposited as a colloid *in situ*, and thus retaining the structural forms of the original tissue."

I may at once state that there is ample proof that the strata of the Irrawaddi division still contain the salts which were required for the above process.

This may here also be a fitting opportunity to correct an error, which though insignificant enough has been the source of the erroneous idea regarding the origin of the Irrawaddi division put forth in the 2nd edition of the Manual of the Geology of India. Mr. Theobald's statement that the silicified wood is never bored by xylophagous mollusca, has been used as a strong argument against the estuarine origin of the "Fossil wood group." The statement that the silicified wood is never bored by xylophagous mollusca is absolutely erroneous, as I have repeatedly found large pieces which have been riddled by the borings of these mollusca. Such pieces are rather rare, but still they exist, and with their existence the whole argument based on their absence falls through, which is another proof of the fallacy of negative proofs.

To conclude the palæontological features of the Irrawaddi division, I may mention here the curious flint flakes which have been found by me in the ferruginous conglomerate at the base of the group and which I described in a separate paper.[1] I may mention here that in the meantime several experienced colleagues have expressed their opinion that these flakes are in reality of artificial origin. As this is not a fitting place for the discussion of this question I simply record the fact without going into details.

d. Subdivision of the Irrawaddi division.

It is quite clear that the same reasons which render a subdivision of the Pegu division, extremely difficult apply also to the Irrawaddi division, even perhaps in a greater degree. It seems an almost hopeless task to subdivide this series of sandstones, clays, etc., of which the lowest exactly resemble in appearance a bed at the top of the series. But even after succeeding in working out a subdivision of a special locality, it is extremely difficult, if not almost impossible, to correlate the subdivisions of two somewhat distant localities, without having the connecting links.

Mr. Theobald's subdivision of the Fossil wood group in Lower Burma, as well as my own for the country around Yenangyoung, cannot therefore have more than local value. It may perhaps be probable that my subdivision, based on palæontological evidence, will eventually prove to be applicable over a larger area, but for the present there is no further support in aid of this supposition.

Mr. Theobald divides the Fossil wood group in descending order as follows:[2]—

[1] Records of the Geolog. Survey of India, volume xx, page 101.

[2] Op. cit., page 62.

a. Fossil wood sands.—Sand, in parts gravelly and conglomeratic, characterised by the profusion of concretions of peroxide of iron, associated with it. Fossils: Trunks of silicified exogenous wood, and, locally, mammalian bones. In the subordinate beds of conglomerate, rolled fragments of wood as above, silicified (that is, mineralized subsequent to their entombment), mammalian and reptilian bones and teeth of cartilaginous fish (squalidæ).

b. Fine silty clay.—Fine silty clay with a few small pebbles, mixed with sand, in strings here and there; the whole very fine and homogeneous and devoid of fossils.

c. Mogoung sands.—A mixed assemblage of shales, sands and conglomerates, the last very subordinate, partaking much of the charactersof beds *a* and *b*; a little of the concretionary oxide of iron. Fossils: rolled wood silicified, mammalian and reptilian bones and cartilaginous fish teeth. Towards the base, the beds contain marine shells and pass into those of the next group.[1]

For the country around Yenangyoung I divide the Irrawaddi strata into the following subdivisions in descending order:—

1. Yellow, soft and friable sandstones, alternating with beds of brown clay. Fossil wood not very common, no fossil bones.

2. Zone of *Mastodon latidens* and *Hippopotamus irravadicus.* Lithological characters as above; fossil wood very common.

3. Zone of *Hippotherium antelopinum* and *Acerotherium perimense.* Ferruginous conglomerate.

These three zones are of very unequal thickness, and although the boundary between zones 3 and 2 is a very sharp and natural one in a palæontological as well as in a lithological sense, yet that between the two upper zones (2 and 1) is more or less artificial, the division being simply based on the apparent absence of fossil bones in the upper beds of the series following immediately above zone 3. As a more detailed description of the development of the Tertiary system near Yenangyoung will be given in the memoirs of the Geological Survey of India, Vol. XXVII, it is unnecessary here to dwell any longer on this subject.

d. Distribution.

The Irrawaddi division caps the older Tertiary beds nearly everywhere in Upper Burma within the boundaries of the basin of the Irrawaddi. Of course it varies considerably in different parts of Upper Burma, but it can always be easily recognised. In Lower Burma it seems to cover a much smaller area, being apparently much eroded, so that only isolated patches remain, while in Upper Burma it forms a continuous cover, stretching from the foot of the Arrakan Yoma as far as the foot of the Shan hills.

The following table shows the manner in which I have subdivided the

[1] *Viz.*, Pegu group.

Burma Tertiaries, with the names given to each subdivision; these are arranged in such a way that at a glance it may be seen what principles have guided me:—

Character of fauna.	Name of Series.		Character of Deposits.	Character of sediments.	Name of division.	
Terrestrial and Fluviatile.	Burma series.		Deltaic.	Yellow sandstones, olive-coloured clays, ferruginous conglomerate; no gypsum.	Irrawaddi division.	
Marine	ARRAKAN SERIES.	UPPER.	Littoral and Estuarine.	Yellow sandstone, olive coloured and bluish clay; gypsum.	Yenangyoung stage.	Pegu division.
				Grey sandstone, bluish clay.	Prome stage.	
		LOWER.	Littoral	Limestone, grey sandstone, bluish clay.	Nummulitic division.	
			Deep sea	Shales	Chin shales.	

In concluding this sketch of the Burma Tertiaries, the following table will convey my views as to the correlation of the Tertiary strata in Burma, India and Europe. It would, of course, be useless to attempt anything beyond a general comparison, and, I think, we must be satisfied if we recognize with some certainty the large sub-divisions of the European Tertiaries in distant Burma.

The Tertiaries of India, of which those of Burma form only the eastern continuation, exhibit, by their remarkable division into two large groups differing widely in the character of their respective faunas, such peculiarities that any correlation with the Tertiary rocks of Europe, except one based on the broadest lines, is almost impossible, a fact which has already been noted by Dr. Blanford.

Europe.	Burma.				Western India.	Himalaya, North-West area.	Himalaya, Simla area.
Pliocene.	Burma Series.			Irawaddi division.	Manchhar group.	Upper Siwaliks.	Upper and middle Siwaliks.
Miocene	ARRAKAN SERIES.	UPPER.	Pegu division.	Yenangyoung stage.	Gaj group	Lower Siwaliks.	Nahan beds Lower Siwaliks.
				Prome stage.	Nari group	Murree beds	Kasauli group.
Eocene		LOWER.		Nummulitic division.	Kirthar group	Upper and Lower Nummulitic.	Dagshai and Subathu group.
				Chin shales	Ranikot group	?	?

Notes from the Geological Survey of India.

I. Rewah.—" Vindhyans."—Mr. Oldham and Mr. Datta have been at work in the Rewah State, north and south of the Sone river; their surveys have already resulted in most interesting and, in some degree, rather startling facts, some of which are briefly noticed in the Annual Report; but since the latter has been set up in type some new facts are reported by Mr. Oldham. He distinguishes the following rock groups in ascending order:

(*a*) A transition series, into which granitic rocks intrude, locally altering them into schists; Mr. Bose had separated the latter from the transitions as a separate system, but Mr. Oldham shows this to be unnecessary.

(*b*) The transitions are unconformably overlaid by a series of rocks, consisting of a basal sandstone and conglomerate, indistinguishable from similar beds at the base of the so-called lower Vindhyans, followed by a great but indeterminable thickness of red, and occasionally green, slaty rock.

(*c*) This series is again unconformably overlaid by the so-called lower Vindhyans; Mr. Oldham drops that name and returns to the older term of the Semri series first used by Mr. Medlicott for the rocks of the same age in Bundelkhund. He has obtained evidence that this series is distinct from the

(*d*) Kymore group or Vindhyans proper, which rest unconformably on the Semri series.

Gondwanas.—Mr. Oldham re-examined a small coal-field, which Mr. Smith had partly surveyed some years ago; the Barakar age of the rocks has now been established, as they contain Vertebraria, Glossopteris, Schizoneura, etc. Mr. Oldham met with two coal-seams, respectively of 6′ and 5′ 6″ thickness; the former is 1½ miles south-west by west of Ujeini, the latter 2 miles north of Amilia, both places near the eastern edge of sheet 476.

II. Madras.—Mr. Middlemiss was engaged during January in examining the magnesite area of Kanjamallai, regarding which he reports:

(*a*) The ultra-basic rocks of the north-west end of Kanjamallai and the derivative magnesite (first discovered by Mr. Holland) were found to be much the same as those of the Chalk Hills. Their extent is, however, insignificant. Olivine-bearing ultra-basic rocks were found to run in a broken band nearly east to west from near Ellampaddi to the point at which the ridge becomes steeper, towards the high western end of Kanjamallai ridge. Pure olivine-rocks, such as compose much of the fundamental rocks of the Chalk Hills, are wanting here. Chromite was found at the eastern end of the band with the magnesite, running as a vein, 4—5 inches wide, through the serpentinized olivine-bearing rock. The amount of this mineral exposed is small. Excavations alone could decide its worth. The magnesite is too unimportant for economical purposes.

(*b*) South of Kanjamallai, a ridge near Ariyanur is composed of altered ultra-basic olivine-rock very closely resembling the dunite of the Chalk Hills. The same rock "massif" becomes talcose, with beds of rather impure potstone, which is locally excavated for making into vessels. A few unimportant magnesite veins occur in this ridge. Incidentally sections were carried round and across the Kanjamallai ridge, and the valuable magnetite bands were located and mapped on the 1-inch maps as closely as possible. The conclusion arrived at was that only the

lowest band need be considered from an economical standpoint, because it seems to be the only one which contains the richer and compacter form of the ore.

(*c*) Between Macdonald's Choultry and Konganapuram, several veins of coarse graphic granite with mica were traced; they seem to be connected with the Idapaddi veins and mica quarries. The great granitic area of granite veins (in a biotite gneiss), of which the Sankaridrug hill forms one summit was mapped.

Mr. Middlemiss afterwards examined the rocks of Valaiyapatti and reports:

(*a*) *Magnesite and ultra-basic rocks.*—The magnesite occurs in very small quantities. The rocks associated with it resemble entirely those at the north-west end of Kanjamallai, as far as their appearance in the field permits an opinion. The absence here as at the latter place of pure olivine rock or dunite is noteworthy. Forming a long low ridge running east and west from Valaiyapatti there are interesting examples of the above type in close association with a very acid rock, namely, a coarse graphic granite composed almost entirely of pink orthoclase and quartz. Both rocks are intrusive among the basal gneisses of that area in parallel lines. Some good instances of this are to be found west of Valaiyapatti. The graphic granite was probably intruded last.

(*b*) *Charnockite south of Salem.*—Between Muttu Kalipatti and Salem on the Namakal-Salem road occurs a great exposure of Charnockite. From its position, strike and general appearance it is a continnation of the Shevaroy hills massif.

(*c*) *Chalk hills.*—As a whole, the aspect of each magnesite area in the Chalk hills near Salem is that of a series of concentric ellipses (roughly speaking) of rocks of varying composition and basicity.

At the centre of each area occurs the chromite in veins among the dunite and serpentine. Surrounding this is a paler dunite zone (almost pure olivine, partly or wholly converted into magnesite). Surrounding this again is a small ring of rocks containing olivine and pyroxene with sometimes biotite. Surrounding this at certain points come rocks like the last, but with felspar and quartz in small quantities. Finally, surrounding the whole area, come great ridges of hornblende-garnet rocks set among and with the ordinary gneisses of the country.

III. Sind. (*a*) *Salt.*—Mr. LaTouche, while superintending the trial-boring for oil at Sukkur, had occasion to examine a very interesting occurrence of rock-salt in nummulitic limestone. The spot where this mineral is found is about half a mile south-east of the village of Aror, which lies at about 4 miles east of Rohri on the left bank of the Indus. Here the low ridge of nummulitic limestone, which extends from Sukkur and Rohri for about 50 miles southward, is intersected by a broad valley, through which the Indus is said to have flowed in former times. On the south side of this valley, in the precipitous scarp overlooking the alluvial plain of the Indus, a band of nummulitic limestone is found about 20 feet from the base of the scarp, and portions of this band contain chloride of sodium in the form of nests and strings, whilst the whole band possesses a slightly saline taste.

(*b*) *Oil.*—Near the village of Kundra, about 8 miles south of Rohri, the natives of that part of Sind knew of a spot where a strong smell of earth-oil could be perceived, and where they used to drive their cattle during the hot weather, as flies are said to avoid the place, which is in the midst of a sandy plain, the present alluvium of the Indus. Latterly Mr. LaTouche had a well dug to ascertain the cause of the exhalations; at a depth of about 16 feet from the surface, the volume of gas issuing

from the soil became so large that the men employed could no longer work in the hole without danger of suffocation. Indeed, in two instances, they were so overcome for the time being that they had to be hauled up with ropes. It was therefore necessary to continue sinking the well by means of an improvised dredger worked from above, and after a good deal of labour water was reached at a depth of 20 feet from the surface. On continuing the sinking for two feet or so below the level of the water, films of oil began to appear on the water, and on dredging up some of the sand from the bottom these films could be seen oozing from it upon the water. The quantity is of course exceedingly small, but it is enough to show that there is probably an escape of oil from the rocks below the alluvium, sufficiently large to have impregnated the latter, which is possibly some hundreds of feet in thickness at that spot. The indications are sufficiently promising to justify the sinking of a boring here.

The gas which escapes from the well is apparently composed principally of carbonic acid, for a light is immediately extinguished by it. But from its smell it is probably mixed with some gaseous hydrocarbon. It is probably caused by the oxidation of hydrocarbons during their slow passage through the alluvium.

There is no outcrop of solid rock anywhere in the neighbourhood of the well, the nearest being the scarp of nummulitic limestone, which forms a low ridge running south from Rohri and about 6 miles east of the well. The intervening ground is covered by the alluvium of the Indus, and at the bottom of the well, fine dark grey alluvial sand was found.

IV. Gondwanas in Argentina.—Dr. Fritz Kurtz, Professor of Botany at the University of Cordoba Rep. Argentina, writes to Dr. F. Noetling that in 1887 he received some fossil plants from Bajo de Velis in the Sierra de San Luis, amongst which he determined a *Neuropteridium* sp., he considered the species as new and described it as *N. argentinum*, Kurtz. However, after having received Vol. III of Feistmantel's Gondwana flora, he recognized at once that his new species was identical with *N. validum*, Feistm, from the Kaharbari beds.

Since that discovery he received some more fossil plants from Cachente, Uspallata (east slope of the Cordillera) and others from the abovenamed locality: among the latter he recognized :

Gangamopteris cyclopteroides, Feistm.
Neuropteridium validum, Feistm.
Noeggerathiopsis hislopi, Feistm.
Equisetites sp. nov.
Sphenozamites sp. nov.
Walchia (?) sp.

To this discovery, which is of the utmost importance for the homotaxy of the Gondwanas, I may add that it forms an additional evidence for the general similarity of geological structure between the southern part of South America and South Africa; we have in both continents marine devonian strata which have yielded practically the same fauna.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

The 1st May 1895.

RECORDS

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On the Jadeite *and other rocks, from* Tammaw *in Upper Burma: by* PROFESSOR MAX BAUER, *Marburg University:* (*translated by* DR. F. NOETLING *and* H. H. HAYDEN).

In the following pages I propose to describe the rocks collected by Dr. Noetling at the jade mines near Tammaw in Upper Burma, and which are now in the collection of the Geological Survey of India. These specimens including the jadeite and the serpentine (the most important) bear all the characteristics of true rocks.

Jadeite.

Jadeite.—The jadeite forms a fine-grained mass, chiefly white, and bearing at first sight a certain resemblance to marble. The size of the grains is not uniform; they are at times so small as to be indistinguishable by the naked eye, while at times they are somewhat larger, in which case they are characterised by an elongated form and distinct cleavage. On account of the smallness of the grains no single individual could be separated, and further information could be obtained only by means of the microscope. I will, however, first describe the general appearance of the jadeite.

General characters.

The colour of all specimens under my observation is a clear snow-white on fresh fracture; this monotonous white is, however, relieved by beautiful emerald-green spots, which represent the really valuable part of the stone. They are of variable size, being sometimes as large as a lentil or a pea, sometimes attaining a diameter or several centimetres. The colour is in many cases very intense, but in others again quite pale, at times forming a faint film-like covering over larger or smaller portions of the surface. As it approaches the white mass of the rock, the colour changes abruptly, without, however, there being any well-defined boundary between the two. The green colour is due to the presence of a small quantity of chromium, for powder of an intensely green colour gives an unquestionable Cr. reaction before the blowpipe: this, however, is less distinct when paler powder is used, and is entirely absent in the white portions of the rock. In the inner portions, when fresh, the lustre is vitreous, but towards the surface becomes somewhat duller. The fracture is uneven and splintery, while the hardness exceeds that of felspar, but is not so high as that of quartz. The tenacity is not very high; at some places splinters can be easily removed. This character varies, however, in different specimens, and at times even in the same specimen. This I believe to be due to disintegration, and also in part to cataclysmic structure, which, as we shall presently see, is a characteristic feature of the jadeite from Tammaw.

Specific gravity.

Special care was exercised in the determination of the specific gravity owing to the fact that in samples of jadeite from Bhamo, which might perhaps be considered identical with specimens from Tammaw, it was found to be very low. The average specific gravity of the Tammaw jadeite is about 3·3, while Issel gives that of two specimens of green jadeite from Bhamo, as 3·10, which corresponds with the values obtained by Damour. Mallet states that the s.g. of the Tammaw jadeite is 3·24. Six specimens of different degrees of coarseness served for my observations. In all of them the s.g. is high, and averages about 3·3, being sometimes higher, sometimes lower. By means of the hydrostatic balance and the pyknometer the following figures were obtained:—3·338, 3·332, 3·330, 3·329, 3·327, 3·325. No connection could be traced between the specific gravity and the texture of the rock. This variation of the s.g. is probably due to small differences in the chemical composition. It is, however, difficult to explain the wide divergence of the results obtained by Issel, Damour and others, and only by the examination of the s.g., chemical composition and microscopic characters of further material can we hope to solve this difficulty. All this, however, should of course be done for one and the same piece.

Chemical composition.

Dr. Busz has made an analysis of one of the coarse-grained pieces (s.g.=3·332), using as fresh and pure a portion of the rock as could be obtained. The results of his analysis are given under I. He specially notes the absence of chromium and oxides of iron.

	I.	II.	III.	IV.	V.
$Si\,O_2$	58·46	59·27	57·63	58·99	59·45
$Al_2\,O_3$	25·75	25·33	24·10	24·77	24·32
$Fe_2\,O_3$	...	...	...	·32	·36
$Ca\,O$	·63	·62	·62	·14	·22
$Mg\,O$	·34	·48	·48	Traces.	
$Fe\,O$	...	·71	·71	...	...
$Na_2\,O$	13·93	13·82	13·82	14·51	14·42
Loss	1·00	...	...	1·14	1·15
	100·11	100·23	97·36	99·87	99·92

The figures obtained by my analysis (I) very nearly agree with those obtained by Damour from a jadeite from Asia (II). If we adopt the views expressed by E. Cohen (Neues Jahrb. für Min., etc., 1884, Vol. I, p. 47), the jadeite under examination as well as that analysed by Damour would have the following composition:—90·1 per cent. of $Na_2\,O, Al_2\,O_3, 4\,Si\,O_2$, 4·59 per cent. of $Mg\,O, Al_2\,O_3, 4\,Si\,O_2$, 1·28 per cent. of $Ca\,O, Si\,O_2$. On the other hand the silicate $Fe\,O, Si\,O_2$, which has been found in most other jadeites, is entirely absent, while in that from Asia 1·3 per cent. is present. Column III represents the average of I and II, while IV and V give the figures obtained by Oliver C. Farringdon[1] from an analysis of jadeite from Mogaung.

Microscopic characters.

The microscopic examination shows that the ground-mass is composed of a confused aggregate of irregular prisms, varying in size; their length and breadth being in some cases the same, and nearly equal to 1 mm., but as a rule the prisms are elongated, their length considerably exceeding their breadth. In no case, however, did I observe a breadth

[1] Proceedings of the U. S Nat. Museum, Washington, 1894, Vol. XVII, No. 981, pp. 29–31.

of less than 0·1 mm. The ground-mass of the jadeite is perfectly pure, and without a trace of any accessory mineral. The prisms are perfectly colourless, except at the boundary between two individuals or along small cracks, where a slight discolouration may be seen, probably due to subsequent infiltration. The green spots always retain their colour even in slices: it is, however, very pale, even in cases in which it was originally intense. In very pale sections no pleochroism is noticeable, but thicker slices are slightly dichroic, the colours ranging from a bluish to a yellowish green. The prisms are at times colourless in places. In the centre of the green spots they are coloured, but as they approach the surrounding white ground mass, they begin to lose their colour, and become partly green and partly white. Hence we see that the green patches in the white ground cannot be due to an aggregation of green mineral grains at certain spots, but we must imagine local inpregnations to have taken place by means of a colouring matter containing chromium in solution. This permeates each spot with such uniformity that it does not appear to have any well-defined form even under the highest powers of the microscope. The green prisms are exactly similar in every respect to the white ones, with the sole exception of their different colour. No pitting of the surface can be noticed, the crystals appearing perfectly smooth: hence their refractive index is not high. Very minute liquid enclosures are locally numerous, occurring at some spots in aggregates of several individuals: more often, however, they are entirely absent. The characteristic cleavage of augite is very frequently extremely well-marked. In cross-sections the two cleavages intersect almost at right angles. The angle, however, depends of course on the direction in which the section has been cut. In none of my observations could I discover any difference in the two prismatic cleavages, which appear to be everywhere equally perfect. Hence, the cleavage of jadeite certainly does not justify us in including it among the triclinic minerals. In addition to prismatic, pinacoidal cleavage also occurs, and still more frequently, a cleavage transverse to the prismatic zone similar to that of diopside and other pyroxenes. The angle between the cleavage in this direction and that parallel to the prism faces is about 90°. I obtained values up to 96°, but this angle depends of course on the direction in which the slice has been cut. These cleavages frequently subdivide the prisms into single segments, having a strong resemblance to cross-sections of the prisms. They differ, however, from the latter in being less regular.

In polarised light, the prisms show very vivid interference colours. On sections with oblique extinction, the angle of extinction is very high, rising to 40°. Numerous longitudinal sections, however, have straight extinction, one direction being parallel to the cleavage and the other normal to it. In convergent polarised light the perfectly transparent crystals give very fine and clear interference figures, while owing to the thinness of the slide the narrow rings, as well as the vivid polarisation colours in parallel light, indicate a strong double refraction. According to the direction in which the section has been cut, these figures show the well-known differences in shape. On longitudinal sections, however, with straight extinction, one or two axes always undergo dispersion, with a wide axial angle, and the plane of the optic axis is parallel to the cleavage and perpendicular to the direction in which the section has been cut. If we include jadeite in the monoclinic system, then these sections are parallel to the axis of symmetry and the axial plane becomes the plane of symmetry. The above optical property is intimately connected with the crystal-

line form, and corresponds to that of all other monoclinic pyroxenes, which, without exception, show inclined dispersion. This, however, cannot be observed in the case of jadeite, owing to its wide axial angle. If, on the other hand, we place jadeite in the triclinic system, these optical properties will be anomalous. It seems therefore impossible to suppose that the mineral belongs to that system. It is true that in cross-sections, the directions of extinction are frequently not symmetrical to both cleavages. This symmetry, however, is found in the monoclinic system only when the direction in which the slice has been cut is parallel to the axis of symmetry. Otherwise, the direction of extinction forms different angles with the two systems of cleavage, and the difference of the angles depends on the more or less symmetrical position of the cleavage prism with regard to the plane in which the section has been cut. The optical symmetry is therefore no proof of the triclinic character of the mineral; and in our special case has absolutely no weight, inasmuch as cross sections also occur showing optical symmetry. The above refers chiefly to the properties of a single individual of jadeite. These, however, are frequently intergrown, and at times occur as a number of long prisms, forming a divergently radiating group with interpenetration, and producing a perfectly uniform groundmass. The longitudinal axis of the prisms do not point in any one direction more than in another, hence the groundmass consists of an aggregate of completely directionless individuals. In none of the specimens, however, is the original structure entirely unchanged. Frequently it is locally very distinct, but equally frequently it is more or less disturbed, in which case the prisms are no longer straight, but become more or less curved, and not infrequently distorted and broken: the fragments are then pushed out of place and a differently oriented substance squeezed in. The distorted prisms frequently exhibit at their ends a sort of fringing, which like the distortion is the result of mechanical action. The result of this action, however, is not merely bending and distortion, or fracture and fringing at the ends, but it even extends to the total smashing of the entire groundmass, which then no longer consists of elongated prisms, but becomes an "aggregate-polarising" agglomerate of small grains, which are the remains of the crushed prisms. Some of the prisms still remain in the fine-grained aggregate, but they clearly exhibit bending, distortion or some form of deformation. Sometimes it is possible to trace a transition from the fine grains to the complete prisms. In fact, this is one of the finest instances of cataclysmic structure, which can only be explained by means of violent compression of the already formed rock. The structure is of course better developed in some specimens than in others; but wherever it is well-marked, two other phenomena may be observed in those jadeite prisms which have been preserved: these are evidently due to the same causes as the cataclysmic structure. One of these phenomena is an undulating extinction which is apparently attributable to a slight deformation of the jadeite prisms. The other is polysynthetic twinning, so similar to that of plagioclase, that at first glance the twinned jadeite crystals might easily be mistaken for that mineral. The jadeite twins, however, gradually pass into single prisms, and the general properties of the twinned crystals are so exactly similar to those of the single individuals that no doubt of their identity can be entertained. The twin lamellæ are not very broad: in fact, as a rule, they are narrow; they are always numerous, more particularly in the latter case. Twinned prisms are frequently bent throughout and

fringed at the ends. It appears that the twins are most numerous in the portions that have suffered the greatest crushing, and are absent where the effects of pressure are not well marked. We must conclude, therefore, that under favourable conditions crushing and pressure would produce in the jadeite a re-arrangement of the molecules into twins, similar to that observed in calcite. This, however, must have happened only in rare cases, for it had not hitherto been observed. The twinning, plane, which in this case must be looked upon as a fault-plane, is distinctly seen to be a transverse plane, corresponding to that otherwise observed as a twinning-plane in pyroxene.

2. *Serpentine.*—The groundmass of the serpentine is dense, appearing completely homogeneous, with a very dark, somewhat brownish-green colour, which spreads evenly over the whole surface. Fracture uneven and splintery. Hardness considerable, exceeding that of pure serpentine: apatite is distinctly scratched in some instances. Under the microscope the cause of this anomaly is at once evident; for the specimen is seen to be an altered olivine-rock, the alteration of which into serpentine is not quite complete, but the process of serpentinization is proceeding in the usual manner along cracks and fissures. In microscopic sections, the olivine is perfectly colourless and transparent: in thick slices, however, it shows a greenish-yellow tinge. It forms an aggregate of rather coarse grains, which in several instances have a diameter of more than 1 cm. They are always irregularly circular, no indication of crystal faces being traceable. Between the larger grains, which throughout the slide extinguish simultaneously, occur aggregates of very minute, confused and variously oriented grains, which appear to be derived from larger olivine grains. This phenomenon seems to be analogous to the cataclysmic structure of the jadeite, a view which is supported by the fact that the serpentine possesses other properties which are undoubtedly due to mechanical pressure. The olivine individuals and also the aggregates formed by the small grains are intersected in the usual manner by strings of serpentine of a greenish-yellow colour, which usually show a distinct and very fine fibrous structure, running in most cases parallel to the walls of the small fissures: in a few cases, however, they are perpendicular to the walls. The rock is therefore a fibrous serpentine, very similar to chrysotile, and closely resembles it in the vividness of its polarisation colours. In microscopic slices these rise to the blue of the 2nd order, but by a combination of several fibres lying one upon the other, fall at times to an iron-grey of the 1st order. In all fibres, the direction of extinction is parallel to the fibres, corresponding to the axis of least elasticity as in the case of chrysotile. The strings intersect each other very irregularly as a rule, but occasionally cross in straight lines at right angles to one another, in which case, when the olivine appears dark in polarised light, a regular mosaic-like structure is produced. With the exception of numerous small black grains, with metallic lustre, no other minerals but olivine and serpentine can be seen. These black grains having a diameter of 1 mm., are magnetic, and hence are probably magnetite. B. b. they give no titanium reaction. Some of the grains are not magnetic, and in the borax bead give a marked Cr. reaction: they must therefore be chromite or picotite, most probably the former, as they did not appear to be particularly hard. These grains are unquestionably the

Serpentine.
General appearance.

Microscopic characters.

Olivine.

Serpentine.

Magnetite and other accessory constituents.

source of the Cr. which permeates portions of the jadeite, producing the green patches. In the specimens under observation, however, no mineral can be identified as chromite or picotite; if, however, a larger number of specimens were examined, I have no doubt that sections of both minerals would be found. Under the microscope, the grains of magnetite exhibit very regular octahedral outlines; they are sometimes single, but not infrequently form parallel aggregates of small individuals, which, however, are not true skeleton crystals. The whole of the magnetite is always found among the serpentine fibres, and not a trace can be discovered in the fresh unaltered olivine: it is therefore unquestionably a secondary product of the alteration of the olivine into serpentine. A specimen of the serpentine rock, which had been freed as much as possible from magnetite, gave a s. g. of 2·838. If we take the s. g. of pure serpentine as being that of the pikrolite from Amelose, *viz.*, 2·551, and further if we take the s. g. of pure unaltered olivine as being that of chrysolite from the East, *viz.*, 3·331, we deduce from the s. g. of the serpentine from Tammaw (2·838), the fact that it contains 43·19 per cent. by weight of olivine and 56·81 per cent. of serpentine. The percentage by volume being—

Specific gravity.

Composition.

Olivine	36·79 per cent.
Serpentine	63·21 ,, ,,

These figures are of course not absolutely correct, but give a very fair idea of the composition of the groundmass, and certainly prove that not more than one half of the original olivine has been altered into serpentine. The newer portions of pure serpentine, usually observed in connection with this form of alteration, are not absent in the present case. Strings of pikrolite, in particular, may be seen running through the rock. These veins are of lighter colour than the chief mass of the rock, and are, as a rule, very narrow. Some, however, attain a thickness of nearly 2 cm. Some specimens, the outer surface of which is composed of pikrolite, exhibit the characteristic course, straight, striated appearance, producing the effect of a slickenside; and one of these specimens gives unmistakable evidence of the tremendous crushing and pressure which I have already mentioned. Numerous fissures distorted and bent and sometimes very complicated pass right across the striations, occasionally dying out and being replaced by new ones. They are partly filled with finely fibrous serpentine, resembling chrysotile, the fibres of which are usually normal but sometimes oblique to the walls of the fissure. Occasionally they contain pikrolite, of varying microstructure, of which I shall speak presently. The striæ on the pikrolite are displaced by these fissures, producing step-like markings on the striated surface. Sometimes, in consequence of this displacement, single parts are forcibly bent, and the pikrolite more or less squeezed into the olivine and serpentine. Evidence of the same crushing may also be seen in other specimens of the serpentine. In one case the result is a number of thin lamellæ, while the whole mass is squeezed into an irregularly rounded lenticular form, the rock having a soapy feel. On fresh fracture, the pikrolite has faint fatty lustre, but on the natural surface this lustre is much more marked. The colour is light green, with a distinct greyish or yellowish tinge. Only very rarely is the colour uniform, darker patches usually occurring here and there. The surface of the specimens, and at times even the walls of the inner fissures, are covered with a thin layer of a

Pikrolite.

white substance of lustre varying from mother-of-pearl to fatty. Like the serpentine fibres which intersect the olivine, the pikrolite contains much magnetite in the form of irregular grains, some of which are as large as a pea or even a hazel-nut. I have found no non-magnetic metallic grains, nor could I obtain any Cr. reaction. To the naked eye the pikrolite is perfectly opaque.

In places, the newly formed mineral is coarsely fibrous, the fibres being bent and curved, and the mass having the appearance of metaxite. True chrysotile, recognisable by its peculiar silky appearance and metallic lustre, does not seem to occur in large quantities. The specimens under observation show indications of it, but not its typical development. Under the microscope, the pikrolite is light yellow, almost colourless, and not pleochroic. It can hardly be distinguished from the surrounding Canada balsam, and must therefore have the same refractive index. Brownish patches occur here and there in the colourless groundmass, these are due to infiltration of hydroxide of iron. Their structure is always radial to fibrous, but the fibres are not so fine as those of the pikrolite. Not infrequently, broader fibres occur, forming divergent clusters. Like the single rays and fibres these clusters cross one another confusedly at various angles. Larger grains of magnetite are fairly common, always quite fresh and intimately associated with the rays and fibres, at times completely surrounding them and producing the effect of fluidal structure. The polarisation colours are blues of the second order, and, more often, iron-greys of the first order.

The pikrolite which occurs in strings and fissures, differs from that just described. This variety is formed in the centre of small radiating fibrous clusters, which in polarized light very distinctly show the black cross: the more nearly they approach to the walls of the fissures, the smaller do these clusters become; and they decrease in size more and more, till at length they disappear, becoming so small that even under the highest power of the microscope (× 600) they cannot be individualised. In this case, the whole seemingly structureless mass exhibits in polarised light an iron-grey colour, in which may be seen here and there a black cross, due to some larger clusters embedded in the minute ones.

I have already mentioned a white mineral which covers the surface of the plates of pikrolite and fills up the fissures. To judge from its mother-of-pearl lustre and soapy feel one would be inclined to identify it as talc. Under the microscope, however, it is seen to be a confused mass of mineral fibres resembling pik rolite;but whether it is fibrous pikrolite or chrysotile can only be determined by chemical analysis, for which the material at my disposal is not sufficient. It is highly probable that, comparatively speaking, a large proportion of this mineral composes the intermediate layer between the serpentine and the jadeite. Unfortunately, however, I have no specimens of that layer.

Certain other substances accompany the serpentine in small quantities. Grown over the pikrolite are small blackish-brown grains, exactly resembling webskyite as first described by R. Brauns. This mineral was discovered in some serpentines derived from palæopikrite from Hessen, Amelose and Reichenstein in Silesia. In miscroscopic slides, these grains become of a light brown colour and transparent, being scarcely affected by polarised light. Unfortunately there is not sufficient material for a more exhaustive examination, but such characteristics as I have succeeded in observing, agree so well with webskyite that there can be no doubt as

to their identity, and R. Brauns was therefore correct in assigning such a wide distribution to that mineral. In addition to the above mineral, there occur small rounded or string-like and very fine-grained portions of a mineral of yellowish colour, not affected by hydrochloric acid. This may possibly be a hornstone quartz, such as is frequently found in serpentine. Carbonates, which are not uncommon in serpentines, are entirely absent, for no trace of effervescence could be observed either with hot or cold HCl.

Albite-hornblende rock.
General appearance.

3. *Albite-hornblende rock.*—The only specimen under my observation is of about the size of the fist, and apparently formed part of a large boulder exhibiting both rolled surfaces and fresh fracture. The rolled surface is brown owing to impregnation by hydroxide of iron, the coloration extending for some distance within the rock, but gradually fading and eventually disappearing. At the first glance, one would be inclined to identify this rock as a saussuritic gabbro, owing to the appearance of the fractured surface. The fine white sugary groundmass contains grains of a brown mineral, which cleaves easily and has a metallic lustre on the cleavage faces. Examination proved, however, that these two component parts are neither saussurite nor diallage, and hence the rock is not a saussurite gabbro, but represents a new type. The beautiful, snow-white groundmass is almost indistinguishable from some saussurites, as, for example, from that of Hamberge near Frankinstein in Silesia. It has the hardness of felspar, and fuses with great difficulty before the blowpipe. The s.g. of two fragments were 2·599 and 2·576, which gave an average of 2·587.

Specific gravity.

Microscopic characters.
Albite.

Under the microscope, the groundmass is seen to be a homogeneous aggregate of very small irregularly rounded grains, varying in size from ·02^{mm} to a fourth or fifth of that size. These grains are almost perfectly pure; enclosures being entirely absent, with the exception, perhaps, of a few small liquid enclosures with moveable bubbles. The grains are perfectly transparent and colourless, and between them occur foreign particles, which, however, are never included in them. The white grains show no cleavage faces, but are crossed in one direction by a series of fine cracks, indicating a perfect cleavage. In some cases numerous fine twin lamellæ of plagioclase occur: these, however, are not very common. The polarisation-colours are very vivid, and the surface of the grains is perfectly smooth and without any pitted appearance. Some grains give the interference figures of biaxial crystals, with a wide axial angle, which, however, cannot be measured. According to the analysis of Mr. Busz, the white groundmass is composed of—

Chemical composition.

	I	II
SiO_2	64·60	68·62
Al_2O_3	19·92	19·56
CaO	} traces.	—
MgO		—
K_2O	1·02	—
Na_2O	14·01	11·82
	99·55	100·00

It is therefore unquestionable that this represents an aggregate of albite grains most of which are single individuals. This view is also borne out both by the

chemical and physical properties of the mineral. The composition certainly appears to differ somewhat from that of pure albite given under No. II, but we must remember that the groundmass is not entirely composed of pure albite, but also contains the foreign particles, of which we shall presently speak. The groundmass is slightly affected by HCl., and although albite has been stated to remain unaffected by this acid, it is undoubtedly acted on to a certain extent.

Hornblende.

The brown mineral resembling diallage, scattered through the white groundmass, has been proved to be hornblende. It occurs in single crystals of various sizes, the largest being nearly 4 cm. by 2 cm. This, however, is less than the original size of the crystal which was on the surface of the specimen and has been considerably broken. As a rule, the crystals are smaller, but are always as large as a pea. They are not numerous, being scattered throughout the rock. Their outline is generally irregular, although at times rough crystal faces can be made out. The colour is that of brown hair, but sometimes grey, and the cleavage faces have a metallic lustre, resembling diallage or bronzite. Each crystal is bounded by a green margin, while the surrounding groundmass is also coloured green. In both cases, this coloration is due to numerous microscopic enclosures to which I shall presently refer. In all these hornblende crystals, one of the two very well marked cleavage faces is unusually large, and thus gives the crystal its resemblance to diallage or bronzite. The second cleavage is everywhere equally perfect, and these two meet at an angle of 124° 47′, the characteristic angle of hornblende. This value was obtained by measuring three separate splinters, and in every case the results only differed by a few minutes. On one of those splinters a broad plane was observed truncating the obtuse prism edges; this plane corresponds to the orthopinacoid (100, $\infty \bar{P} \infty$) The hornblende showed no signs of fibrous structure.

Owing to the small amount of material at my disposal, I was unable to make an analysis. The green margin, however, as well as those parts of the albite groundmass which surround the hornblende crystals, gave with borax an unmistakable Cr. reaction; but no Cr. could be detected either in the brown or greyish portions of the hornblende or in the white albite. The micro-chemical examination of the hornblende proved the presence of silica, magnesia, lime, iron, and a little alumina but no alkalies. The average s.g. of the brown splinters was obtained in methylene iodide, and proved to be 3·10, being the average of two separate operations. These figures, as well as the cleavage and the other properties of the mineral, enable us to identify it with hornblende. In the Bunsen flame small splinters are slightly discoloured but do not melt. They melt easily, however, before the blowpipe, fusing to a grey non-magnetic glass. Iron must therefore be present in small quantities. Extinction is straight, parallel to the very distinct cleavage-fissures. Thicker slices exhibit very distinct pleochroism, which, however, entirely disappears in thin sections. The vibrations parallel to the axis of symmetry, and therefore perpendicular to the cleavage cracks, are light brownish-red, while those parallel to the cleavage are light yellow, and those perpendicular to both are light bottle-green. These colours differ but slightly in intensity, while the colour changes from red to green or yellow according to the direction in which the hornblende crystals have been cut. Occasionally, especially at the margin of the crystal, the colour becomes a deep bottle-green or even emerald green: this is

most probably due to infiltration of a foreign substance containing Cr. These greenish patches gradually pass, without well-defined margins, into the differently coloured parts. Cross sections having the characteristic hornblende cleavages intersecting at 124°, extinguish diagonally, while the pleochroism varies from brownish-red to green. On longitudinal sections, the angle of extinction is as much as 19°.

Augite.

In the boundary zone between the hornblende crystals and the albite, a large number of needles of a green mineral occur. These are most numerous along the boundary, and decrease in number on each side of it, thus producing intensely green bands round the hornblende crystals. In the albite aggregate, these needles lie in all directions between the albite grains, but are never enclosed by them. In the hornblende, they not infrequently lie parallel to the cleavage, but more often they are disposed quite at random obliquely to the cleavage fissures. They are always straight, and their length, as a rule, is three or four times their breadth in the broader needles, while in the narrower ones the length is much greater. Their sides generally consist of sharp straight lines; sometimes, however, both edges are slightly curved, thus producing spindle-shaped sections. If the ends are not pointed, they are, as a rule, rough and irregularly indented, but never fringed nor bifurcating. The oblique extinction is important, and rises to as much as 36°. Not infrequently square cross sections may be seen, at times extinguishing parallel to the edges. Cleavage is probably present, but it is not well-defined. Transverse fractures obliquely inclined to the longitudinal axis are common. The characteristics above enumerated enable us to identify this mineral with augite. The colour of the larger prisms is an intense bottle-green to emerald-green, and thus produces the green zone already mentioned as occurring round the hornblende crystals. The narrower needles are of lighter colour, while the narrowest are almost colourless. As a rule, the pleochroism is faint, the colours varying between closely related shades of green. The broadest needles, however, occasionally show a pleochroism ranging through bottle-green and dark greyish-blue to colourless. All are perfectly clear and transparent, and entirely free from inclusions. This mineral is most probably a pyroxene, closely related to diopside or sahlite, which derived its green colour from a small percentage of Cr., and is in fact a chrome diopside. Unfortunately the scarcity of the material precludes a more searching examination of this mineral.

Rhombic pyroxenes and other accessory minerals.

I have already mentioned that a small number of brown crystals may be seen between the albite grains. These show numerous cleavage cracks, parallel to which straight extinction occurs. They consist of oblong plates of about ⅓mm. in length, the cleavage running parallel to the longer axis. This is most probably a rhombic pyroxene, not very rich in iron, very possibly bronzite.

Lastly, under a moderately high power, a very fine-grained aggregate may be seen, scattered here and there among the grains of albite, and running in fine strings into the hornblende crystals. This is always associated with a large number of the green to colourless augite crystals already described, which are particularly numerous in this aggregate. In thin sections, under a high power, these aggregates are seen to be clusters of minute radial fibrous spherulites, which between crossed nicols show, more or less distinctly, the characteristic black cross. The substance

is colourless and gives very vivid polarisation colours, but cannot be more accurately determined.

From the above description, it is evident that the specimen under consideration is an albite-hornblende rock, in which the albite grains form a dense groundmass, containing porphyritic hornblende crystals. The remaining minerals have no particular share in the composition of the rock, and are therefore merely accessory constituents.

Hornblende-glaucophane schist. General appearance.

4. *Hornblende-glaucophane schist.*—This specimen has a dark brown surface, in some places rough and in others smooth, but apparently not much rolled. It is a schistose rock of an intense emerald to grass-green colour, and bears a strong resemblance to smaragdite. A closer examination, however, at once reveals the fact that it represents an aggregate of greyish hornblende individuals, largely permeated by green enclosures, which impart to it its remarkable colour. The greyish portions pass in places into a deep green, but in other places again the green colouring matter is entirely absent. The hornblende individuals are most irregularly inter-

Hornblende.

mixed, and show no signs of definite arrangement. They attain a length of as much as 3, and breadth of as much as 2 cm. They have no definite crystalline outlines, but their cleavage is perfect, the angle between the two prismatic cleavages averaging 124½°. This angle could not, however, be accurately ascertained, owing to the frequent distortion of the prisms, which at times even causes a fringing of the ends. The orthopinacoid was observed on one of these prisms; it gives rather indistinct cleavage, and sharply and straightly truncates the obtuse prism edges. Thin splinters melt in the Bunsen flame; the thicker ones easily fuse before the blowpipe, forming a greenish-grey non-magnetic glass. It is not acted on by HCl., either before or after fusion. The s. g. of the *whole mass*—not that of the pure hornblende—was obtained from two pieces of the rock, the values being 3·113 and 3·126. I endeavoured to obtain the s. g. of the hornblende after removing the green parts, but it was not possible to separate the green colouring matter from the greyish hornblende.

Chemical composition.

I could, therefore, only ascertain the chemical composition of the whole mass, and not that of the pure hornblende. As we have seen, however, that the whole rock consists chiefly of hornblende, containing only emerald-green crystals, the following figures will represent the chemical composition of the hornblende. Mr. R. Busz, who made analysis I, obtained the following results:—

	I.	II.
SiO_2	53·53	58·76
Al_2O_3, Cr_2O_3	9·10	12·99 (Al_2O_3).
FeO	4·02	5·84
CaO	6·94	2·10
MgO	15·94	4·01
Na_2O., K_2O.	7·96	6·45 (Na_2O).
Loss	2·95	2·54 (H_2O).
	100·44	102·69

In the above analysis the very high percentage of alkali is remarkable: it consists chiefly of Na., containing only a small percentage of K.; $Cr_2 O_3$ and $Al_2 O_3$ were not separated. It seems, however, that no small quantity of $Cr_2 O_3$ must be present, for vividly green splinters give an undoubted Cr. reaction in the blowpipe flame. On the other hand, the grey hornblende hardly gives any tinge to the borax. The iron has been calculated as Fe O. According to the above analysis, the mineral proves to be an amphibole, containing a considerable amount of soda, thus resembling glaucophane, which, however, is distinguished by its dark blue colour from the mineral under examination. There are, however, grey varieties of glaucophane. The glaucophane most nearly allied to this mineral is that of Zermatt, the analysis of which is given under II. In both, the percentage of alkali, magnesia and iron very nearly agrees, as also the loss due to ignition. The difference in the percentage of $Al_2 O_3$ is rather more marked, while the difference in the silica is the most pronounced. There are, however, other glaucophanes, which, in this respect, closely resemble the mineral from Burma, *e.g.*, that from New Caledonia contains, according to Liversidge, only 52·79 per cent., while that from Sanjaron in Andalusia contains, according to Barrois and Offret only 47·4 per cent. of $Si O_2$. In the last mentioned variety, also, a low percentage of alumina corresponding to our 8·42 has been observed. From the majority of glaucophanes our mineral differs chiefly in the percentage of lime, for they do not as a rule contain more than 2 or 3 per cent, of CaO. Some, however, are known to contain a larger percentage, *e.g.*, that of Shikoko in Japan, which has a percentage of 4·80, while the glaucophane from Andalusia contains 12·90 per cent.

Glaucophane.

We are therefore undoubtedly entitled to consider this mineral as a glaucophane, inasmuch as its s.g. exactly corresponds with that of most glaucophanes, of which the s.g. ranges from 3·103 to 3·113, the average being 3·12, corresponding to the variety from New Caledonia. The low fusibility is another distinguishing feature. It is a remarkable fact that together with jadeite, which is a pyroxene, there should occur an amphibole, which, owing to its large percentage of Na. closely resembles it in composition. The strong pleochroism peculiar to the dark blue glaucophane is of course less pronounced in the mineral from Burma. In moderately thick slices, however, considerable differences of colour may be seen on rotation of the polariser. The vibrations parallel to $\mathfrak{a}$ are bluish-green, those parallel to $\mathfrak{b}$ greenish-brown and those parallel to $\mathfrak{c}$ yellowish brown, the absorption being $\mathfrak{b} > \mathfrak{a} > \mathfrak{c}$. In thinner slices the same colours appear, being, however, much paler, the differences being therefore less noticeable, while in very thin slices, they almost entirely disappear. The large extinction angle of the Burmese variety contrasts strongly with that of true glaucophane, in which it amounts to only a few degrees, while in the mineral from Tammaw it rises to 28°, a value much higher than that of other rock-forming amphiboles. Under the microscope, cross-sections show the characteristic prismatic cleavage of amphibole. In longitudinal sections the cleavages are very close together, thus producing an appearance of fibrous structure; and, as in the case of the prisms, these fissures are considerably distorted, while the ends are more or less fringed. There can be no doubt that these phenomena are due to the pressure which all the rocks of Tammaw have undergone. In longitudinal sections, also, may be seen an ill-defined transverse cleavage, running obliquely to the

ordinary cleavage fissures. This most probably, as in other amphiboles, represents a cleavage parallel to $\bar{P}\infty$ $(10\bar{1})$, which is a very characteristic feature of glaucophane. Thus we see that the Tammaw mineral differs from true glaucophane only in its abnormal extinction angle.

Augite.

As already mentioned, the hornblende contains numerous fine needles or narrow prisms, which are always elongated in one direction. These are composed of a beautiful emerald-green augite, and produce the fine green colour of the rock, whenever they occur in any quantity. This colour we have already stated to be due to a small percentage of Cr., the very green grains giving a distinct Cr. reaction, while the grey crystals show no such reaction. These enclosures are very similar to those noticed above as forming part of the albite-hornblende rock. The latter, however, do not exhibit such a vivid emerald green, being rather of a bluish-green colour. As in the former case, their lateral boundaries are regular, but their ends are not infrequently fringed or pointed, in which case they assume the spindle-shape already described. The small needles are sometimes arranged very irregularly, but, as a rule, they lie parallel to the vertical axis of the amphibole prisms. The larger non-prismatic crystals form radiating groups, the ends of which are slightly curved and which, owing to their green colour, form a striking contrast to the colourless amphibole. Single crystals become alternately bright and dark in polarised light. The clusters, however, never extinguish entirely, for differently oriented crystals overlap each other. Cross sections show the typical form of augite, but prismatic cleavage is not well marked, the cleavage fissures being somewhat irregular. Transverse fissures, probably representing a transverse cleavage, as in diopside and other pyroxenes, are sometimes seen.

The angle of extinction is fairly high, but it is difficult to obtain measurements of it. Since the larger prisms never extinguish completely, while the smaller crystals are bounded by curves, straight cleavage-fissures being almost entirely absent. In some cases, however, I obtained values up to 50°. The pleochroism is very marked. Cross sections of moderate thickness, however, exhibit only slight differences of colour, the bluish-green remaining almost unchanged during a complete rotation of the polariser. On longitudinal sections, the differences are much more marked, the vibrations in the direction of the axis of elasticity being greenish-yellow, with at times a shade of uranium glass, while those normal to this axis are bluish green as in the cross-sections. Hence during rotation the colour varies between the above tints. Even in very thin slices, this is still visible; the very thinnest needles, however, having no distinct colour, have no pleochroism. The green material occurs in a different manner to that enclosed in the hornblende. The hornblende is frequently intersected by green strings, entirely composed of crystals of augite, as in the previous case. These are, however, of much smaller dimensions, and are, in fact, almost microlites. In rare cases circular clusters of such augite microlites have been observed filling up the fissures and other small cavities in the hornblende, while the larger augites, already described, were unquestionably developed at much the same time as the amphibole, in which they are enclosed; and there is no indication whatever that they were produced by subsequent alteration of the amphibole. It is a remarkable fact that all the Cr. has been taken up by the augite, while none is found in the amphibole.

Geological age.

From the above description of the rocks occurring in the jadeite mines at Tammaw, *viz.*, the jadeite, the olivine-serpentine, the albite-hornblende rock, and the amphibole-glaucophane-schist, we are enabled to form a clear conception of their nature. Noetling believes that the jadeite and the serpentine penetrate the surrounding tertiary sandstone, while with regard to the relations between the occurrence of the two other rocks and the jadeite, nothing is known. Noetling's view necessitates the assumption of an eruption of jadeite and another of olivine rock, following one another; but the petrological composition of these rocks is not favourable to such a view, which would include them among the tertiary eruptive rocks. Judging by the petrological characters, we must consider them as representing a system of crystalline schists.

Now there is no doubt that in former geological times olivine rocks were produced by volcanic eruptions. Nowhere, however, have rocks of this nature been found in beds of such modern date, being according to Noetling not older than of miocene age. Wherever tertiary masses of olivine are known to occur, as for example the enclosures in basalt, they are perfectly fresh, and show no signs of serpentinisation. I wish particularly to emphasize this fact, since the basalt which I shall presently describe, and which occurs in close proximity to the jadeite mines, has no geological connection with the jadeite, but is unquestionably an eruptive rock passing through tertiary strata. In this basalt the serpentinisation of the olivine has just begun, but has not progressed beyond the first stages, while such a complete alteration as that exhibited in the above specimens is characteristic of all ancient olivine rocks—such as palæopikrite—and, as I have already observed, of the crystalline schists.

To consider the jadeite as an eruptive rock would be entirely unjustifiable: for neither in the older nor yet in the more recent series of eruptive rocks has any rock of the nature of jadeite been found. In Turkistan, however, it has been proved to be imbedded with nephrite in the crystalline schists (gneiss and mica schist); and belongs to that series.

The two other rocks also offer material proof in favour of this view, for it is highly probable that the glaucophane-schist is one of the crystalline schists. Hitherto, glaucophane has been found only in gneissic rocks and mica schists, no instance having been recorded of its occurrence in eruptive rocks, much less of its entirely composing such rocks. The same holds good for the albite of the albite-hornblende rock. This mineral frequently occurs as a component part of the crystalline schists, but hardly of eruptive rocks. The peculiar aggregation of the albite grains is in perfect harmony with this view, for such a structure would be by no means remarkable in a crystalline schist. I am therefore of opinion that the jadeite and the other rocks must be looked upon as part of the series of crystalline schists, overlaid by tertiary beds and probably denuded by erosion. It is most probable that they were raised to their present level together with the surrounding tertiary rocks, when these latter were subjected to folding. I have repeatedly laid stress on the fact that these rocks must have been subjected to great pressure, which can only be accounted for by folding. I do not assert for a moment that the above arguments are absolutely convincing, but they certainly support the view which best accords with the petrological evidence, while the stratigraphical conditions observed by Noetling in the mines at Tammaw fully bear out this view. Further observations, however, with regard to the geological conditions of that country, will cer-

tainly decide the question. On the geological map of Burma, west of the Irrawaddi, even west of Mogaung, towards Tammaw, sub-metamorphic rocks are indicated; while crystalline limestones, probably of silurian age, extend to within about two miles of the eastern side of the jadeite mines.

Basalt.

In conclusion, I wish to mention a rock which, although not belonging to the series described from the jadeite mines, has been found on a hill four miles east of Sanka village. It is an excellent felspar-basalt, with blackish-grey fracture, and brown weathered surface. Under the microscope, the felspar—plagioclase—forms a crowd of minute lamellæ, in which only very few individuals are twinned, while a very small number of the crystals are somewhat larger. The felspar crystals form the groundmass in which all the larger constituents of the rock are porphyritically imbedded.

The augite is of a very light yellowish-green colour, without noticeable pleochroism, but with oblique extinction as is usual in basaltic augites. The crystals, which are regularly bounded by straight lines, are usually of considerable size. There are, however, smaller crystals which in their dimensions very nearly approach the lamellar felspars. These small augite crystals form part of the groundmass together with the felspars, but they are not nearly so numerous as the latter. They are much more sharply and regularly bounded than the larger crystals, and probably represent a later generation of augite. As a rule, they are single, but twins are occasionally seen parallel to the orthopinacoid, and not infrequently polysynthetic. Cruciform twins appear to occur, but I cannot state with absolute certainty that any regular intergrowth takes place. The augite, like the felspar, is perfectly fresh, and both are fairly free from foreign enclosures of all sorts. Magnetite, however, generally very regular in shape, is not infrequently included in the augite. Olivine usually forms the largest crystals; it is either perfectly fresh or intersected by a few cracks along which serpentinisation has just set in, only small progress, however, having been made in this direction. It also contains inclusions of magnetite grains. A few dark brown transparent grains of picotite occur, while liquid enclosures containing moveable bubbles are frequently seen, arranged in the well-known zones. Magnetite is fairly common, and usually forms well-defined crystals of considerable size. These crystals sometimes occur singly, and sometimes in larger and regularly-arranged groups. They are partly imbedded in the groundmass between the felspar and augite microlites, and partly occur as enclosures in the larger augites and olivines. As already stated, I consider some of the darker brown and transparent enclosures in the olivine to be picotite. A number of long, colourless needles with straight extinction, and sometimes grouped in clusters, are crystals of apatite. No other minerals have been observed, while glass, in particular, is entirely absent, not a trace of it having been discovered.

The basalt is therefore holo-crystalline and falls under class II of Zirkel's classification, the members of which group are distinguished by a fine-grained, microscopic groundmass, which is crystalline throughout or only contains a small quantity of magma in which larger crystals—in this case augite and olivine—occur. Or if we adopt Rosenbusch's classification, we must describe it as a holo-crystalline porphyritic basalt, in which, notwithstanding the enormous number of plagioclase lamellæ forming the groundmass, no larger plagioclase crystals appear, as is more usually the case. Warm HCl affects the rock but slightly, while cubes of NaCl are not formed after evaporation.

On the Geology of the Tóchi Valley, by F. H. SMITH, A.R.C.S, *Assistant Superintendent, Geological Survey of India* (with pl. 3).

Towards the end of February 1895 I received orders to join the delimitation party at work in the Tóchi valley. A geologist was specially required to ascertain, if possible, whether the reported occurrence of copper and iron in the hills south of the Tóchi river, and between it and the Khaisor, was of economic importance.

Unfortunately, when I received my orders, I was engaged in field-work amongst the southern spurs of the Sulaimán range in Baluchistán, and by the time I caught up the Tóchi column that part of the delimitation work situated in the Tóchi hills had been completed, and I never had an opportunity afterwards of seeing more than the northern or Tóchi flanks of the hills.

Copper and iron.

I may say at once that, as far as I could observe, the hills between the Tóchi and Khaisor rivers contained no minerals of any economic importance. I have not met with any trace of copper, or mineral containing copper during my march along the Tóchi and one or two tributary streams.

The Waziris are said to work and smelt iron ore to a considerable extent in the hills to the south of the Tóchi; and the number of native-made knives seen all over Waziristán shows that there must be a considerable iron industry. The majority of the knives are made of very soft iron, and their value, when sold to Europeans, seemed to be from 2 or 3 rupees each; smaller knives of mottled native steel are fairly common, the price of which seems to run up to anything under 25 or 30 rupees, according to the appearance of the intending purchaser.

The only place where I found any traces of iron ore was Mirán Sháh. There I found several concretions of very pure soft hæmatite, in middle or lower eocene sandstone beds. These beds have *roughly* a north and south strike in this neighbourhood; to the north the series forms the Laram hills, while to the south the hill-country between the Tóchi and the Khaisor, or Khasora, is mainly composed of these same rocks. It is very probable that the iron ore supply is derived from this pure concretionary hæmatite, which could easily be found in sufficient quantities for the manufacture of knives and other small implements, but which would probably run out at once if worked to any great extent. Even if pure hæmatite were found in greater abundance, as is constantly the case in other parts of India, the total absence of fuel would render it useless in this valley.

Although my march up the Tóchi was not very successful from an economic point of view, it was none the less interesting geologically, especially as I traversed new country.

Topography.

Marching from Bannu up the Tóchi valley, one enters the outer range of tertiary hills near Tóchi village, at a height of about 1,000 feet above sea-level. From here to Dotoi, the farthest point I reached, is about 60 miles in a straight line, and rather more along the river bed which runs almost due east and west. At Dotoi the height is about 5,000 feet, and the higher peaks around run up to 10,000 feet. To the west of the outer hills mentioned above, which run roughly north and south, the river bed traverses two

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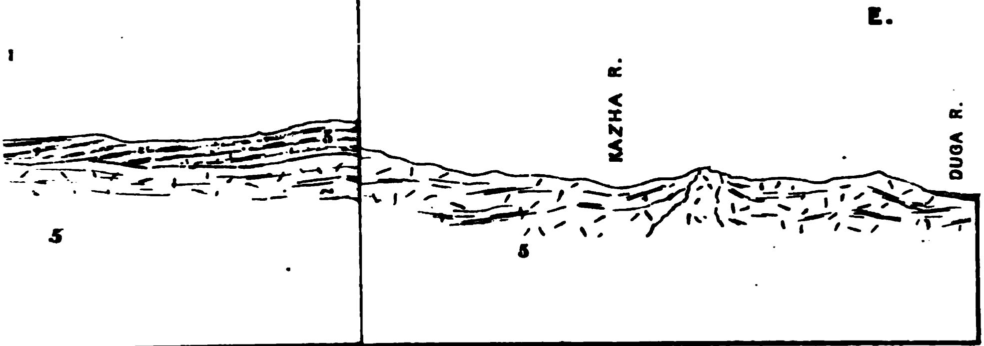

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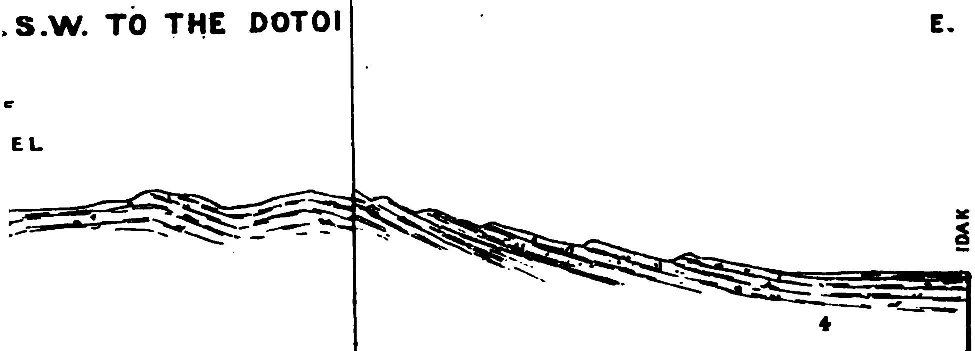

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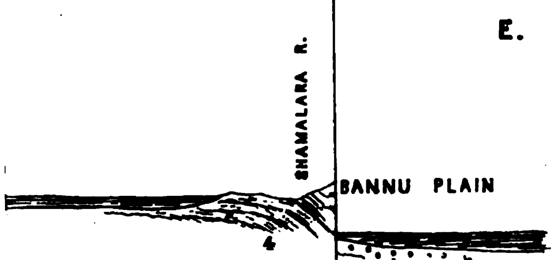

.E. TO BANNU PLAI

d Lower Nummulitic beds. 5.

Zinco., S. O. Calcutta.

wide plains, the Idar Khél and Idak valleys. Both plains are bounded north and south by hills, which close in to the west of Idak, above which the river-bed lies between irregular hills, forming a more or less narrow valley.

I was able also to march up a tributary of the Tóchi, the Kazha nala, which rises on the Luara plateau under Charkhiaghar to the north of Dotoi, and runs nearly parallel to the Tóchi till it joins it near Pakki Kôt.

Geology.

As the newer rocks present none of the difficulties which are met with in the older rocks which I saw, I will describe the section in descending order. Roughly speaking, the younger rocks are found in the eastern outer ranges, which rise from the Bannu plain, and older rocks appear in the interior to the westward.

The rocks in this outer range—the Shinkai hills—showed a most striking similarity in composition and arrangement to those of the Fort Munro range, south-west of Déra Gházi Khán. This latter range, rising from the Indus plain, presents a perfectly normal section of rocks which dip steeply eastwards under the Indus plain; from upper siwalik conglomerate in the outer ranges, through lower siwalik, upper, middle, and lower eocene rocks, with beds of probably cretaceous age at the base. Having just traversed the Fort Munro range, the similarity between it and the Shinkai range rising from the Bannu plain, some 200 miles to the north, appeared all the more striking to me. Evidently the same, or nearly the same, series of tertiary rocks have been disturbed and folded in the same manner, and for a distance of hundreds of miles along the frontier hills west of the Indus plain. Taking the normal section of the Shinkai range from west to east, nearly the same series of beds is met with.

Siwaliks.

The outermost range commences two or three miles to the west of Tóchi village, where the massive conglomerates and grits of the upper siwaliks dip gently to the east under the Bannu plain. The dip becomes steeper further west, and in the highest ridge of these hills the rocks dip very steeply, still eastwards, till along the bank of the Tóchi river it becomes vertical; this dip is maintained westwards throughout the lower siwaliks and upper nummulitics at least. The thickness of these conglomerates must be great, and is probably several thousand feet, but the lower siwalik beds are of even much greater thickness. In the Saidgi valley the rocks change from conglomerate (east) into an immense thickness of sandstones and shales (west). The conglomerate passes gradually and perfectly conformably into finer sandy strata, which at once become interbedded with beds of shale. The lower siwalik beds consist entirely of grey sandstones and red shales; the latter predominate in the upper beds, but give way lower down to soft sandstone beds, which contain no shale bands at the base. The dip is vertical throughout the whole section of these beds across the Saidgi valley and up to the highest ridge of the hills westward. The strata appear not to be crushed to any extent, but are exposed as a perfectly normal section, with an outcrop of fully 2 miles in breadth, which gives the lower siwalik beds the immense thickness of 10,000 feet. I could find no trace of fossils in either the shales or sandstones.

Upper nummulitic.

Along the ridge of the hills west of Saidgi there runs a bed of white hard limestone, under 200 feet in thickness. The dip is vertical, and at Shinkai in the river bed the exact thickness is 170 feet.

The limestone is full of fossils, the harder bands being almost made up of *nummulites* and *alveolinæ*, while some softer muddy bands are full of gastropods and bivalves, with which I found part of a well preserved crab.

The junction of this white limestone with the overlying grey siwalik sandstone is clearly seen in the river bed. In position they are perfectly conformable; the white limestone is very nodular, so that the upper surface is not quite smooth. The sandstone fills up the irregularities, and the bedding of both is perfectly parallel: the sandstone contains many limestone pebbles for about 2 feet from the junction, but the parallelism appears perfect. The junction of this upper nummulitic limestone with the lower beds is not so well seen, but the white limestone appears to rest conformably on the soft shale beds below. To the north of Sheranni, upper nummulitic rocks occupy a considerable area, forming a flat basin north of the Tóchi. The rocks consist of white limestones and interbedded light green shales; the limestone is identical with that at Shinkai. The thickness of the whole exceeds that of the rocks at Shinkai, but the base beds rest on rocks so much disturbed by igneous intrusions that I could make no very definite observations on the lower beds.

Lower nummulitic.

Below the white limestone comes a thickness of 400 to 500 feet of olive green shales, very like the 'ghazij' shales of the Quetta area, which are of middle nummulitic age; at the base of these I observed some red shale bands, below which come 200 to 300 feet of shales, interbedded with shaly limestone and limestone breccia. The breccia contains many fossil organisms, but I have not found any nummulites amongst them; a fossil fruit was found in the associated shales, but nothing could be seen in the shaly limestone.

These shaly beds down to this point may probably represent the middle nummulitics, but they pass so imperceptibly into lower rocks that no distinct division can be made. Below the limestone breccia band the shales become interbedded with sandstones and calcareous sandstones, and dip again steeply to the east. This series of rocks continues from Shinkai to the Idar Khél plain on the west, the dip lessening towards the east on nearing the plain.

The main mass of the rocks consists of soft shales, greenish brown to red in colour, with frequent partings of softish sandstone, buff to brown inside, but always weathering a shiny black on the surface. Some beds appear to have been altered into red coloured porcellanic, shaly limestone bands. Near Idar Khél the sandstone bands, nearly white in colour, increase in size and contain pure limestone bands, layers of sandstone and limestone alternating several times in the course of 2 or 3 feet.

In some places this series is considerably contorted, but on the whole there is a steady easterly dip throughout. There must be several thousand feet of these rocks visible in the section along the river bed. I may mention here that the black weathering of the sandstones and calcareous sandstones is very typical of middle and lower eocene rocks in eastern Baluchistán. In the calcareous sandstones there are traces of organisms, apparently *foraminifera*, but I found no fossils in any of the other sandstone or shale bands.

The Idar Khél plain is cut out of a flat anticlinal of these lower eocene rocks; in the hills east of Idak they dip again gently westwards, but here the predominance of sandstone bands is changed to one of calcareous and limestone bands, which are remarkable for the quantity of corals in them. These beds, hard grey

limestones and shales with some sandstone bands, form the hills south of the Tóchi as far west as Mahomed Khél, and to the north of the Tóchi from Mahomed Khél across to the Laram hills, and from thence down to the hills surrounding the Idak plain.

Mesozoic.

The range of hills between Idak and Mirán Sháh is formed by an anticlinal ridge which approximately strikes north and south, and which is composed of these lower eocene beds. In the core of the anticlinal a considerable thickness of massive dark grey limestone is exposed, in which I could find no fossil remains; the age of this limestone is therefore doubtful, and there is no evidence of any kind to show whether it belongs to the lowest tertiary or upper mesozoic age.

Dotoi beds.

The middle and lower eocene beds between Shinkai and Mahomed Khél are conspicuous by the general absence of undoubted nummulites: corals and the broken shells of bivalves are abundant, but *foraminifera* only occur rarely and then the traces are badly preserved. Round Dotoi, however, beds of apparently lower eocene age appear, yellow limestones with interbedded blue slaty shales, of which the limestone bands are full of fine nummulites of all sizes. These beds have no resemblance to the very white limestones and light green shales of the upper nummulitics, and very little more resemblance to the non-nummulitic rocks round Idak; in fact they show no resemblance to any of the rocks seen in the Shinkai hill section. This may be explained by the amount of igneous alteration which has taken place in the neighbourhood, and which has effaced all evidence of connection between the Dotoi rocks, the upper nummulitics north of Sheranni, and the lower nummulitics east of Mahomed Khél.

Igneous intrusion.

One is much struck on marching up the Tóchi river bed by the great quantity of pebbles and boulders of igneous rocks met with *en route*. The majority of the pebbles, even at Tóchi village, are of diorites, gabbros, and basic rocks. No indication of their being anywhere *in situ* is met with till one arrives within about 3 miles of Mahomed Khél. Here the lower eocene limestones and shales are seen to rest abruptly, but conformably on a series of beds, and are doubtless part of the latter, which are altered by igneous action, but with evidence of having been interbedded with igneous rocks, which in many cases form massive intrusions in the former. This facies of beds covers the country between Mahomed Khél and Dotoi, though it is overlaid by upper nummulitic beds north of Sheranni.

The igneous intrusions are invariably of the more basic rocks. I never found a trace of any acid rock, but diorites are very common, and they, as well as more basic forms, appear to pass gradually into the rocks which they penetrate partially. As generally happens, the beds are altered to such an extent near the junction, that no definite line can be drawn between the true shales on one hand and the true crystalline rock on the other. Throughout the whole area of igneous disturbance I never found anything but shaly beds associated with the igneous rocks.

Age of igneous series.

In some cases the shales have undergone very slight alteration only, but unfortunately I have not found any traces of fossils in beds connected with the igneous rocks, so the only clue to the age of these beds rests on their relative position to other beds. On the west the igneous series is overlaid by the lower nummulitic Dotoi beds, with the bedding more

or less parallel. On the east the Idak series of lower eocene rocks rests conformably on altered shale beds with igneous intrusions. Upper, and perhaps middle, nummulitic beds directly overlay the igneous rocks between these two junctions; the disturbance in the basal beds makes it impossible to see from a distance what connection there is between the upper nummulitics and the igneous series. It is singular that nothing but shaly beds should be found within the area of igneous disturbance. The natural conclusion to be drawn seems to be the supposition that igneous action, in the form of intrusions and deposition of ash beds, began some time before the beginning of the tertiary period; and lasted, with occasional variations causing interbedding, up to the end of middle eocene times.

Series.

The intrusive masses vary a good deal in composition. I found various forms of diorite, but the greatest variety seemed to be in the gabbros, which pass gradually into hypersthene (and diallage) rocks. Some pebbles, of what appeared to be amygdaloidal basalt, occurred in the river bed, but I never found this rock *in situ*. From the diversity of these rocks, ranging from intermediate to basic, and probably ultrabasic forms, coupled with their interbedding with shales and possibly other rocks of eocene age, it seems very probable that this series may correspond to the widespread formation of shales and igneous rocks which form large areas in Baluchistán; the Kójak shales are typical for this lithological formation, which also ranges from the later cretaceous to middle eocene times.

Description of sections.

In the absence of an accurate map, the accompanying sections (pl. 3), which are drawn approximately from east to west across the general strike of the beds, may give some idea of the arrangement of the rocks. The three sections, which are drawn to natural scale of 1 inch = 1 mile, follow the Tóchi river, mostly through the hills directly to the north of it. They do not conform quite to a straight line from east to west, but yet so closely, that they may be taken to represent a continuous section from the Dotoi country to the Bannu plain.

Section I.—To the west the Dotoi beds, considerably disturbed and contorted, form the greater part of the country, and rest near Dotoi village on the igneous series. The junction beds show a good deal of disturbance, as is natural in the immediate neighbourhood of igneous intrusions, and it is doubtful what connection there is between the beds. To the east there appears a flat basin of upper nummulitic beds, quite unaltered, composed of white nummulitic limestone, interbedded with light green shale beds. The base beds of this series is seen here and there to be drawn into the sphere of igneous action, showing that the disturbance lasted up to middle eocene times at least.

Section II.—The Idak series of lower nummulitic beds rests on the igneous facies, just north of Mahomed Khél. Igneous disturbance seems to have ceased half way through lower eocene times, leaving the upper half to the east unaltered. The only break in these beds to the east, as far as Idak, occurs in the anticlinal ridge of older limestone between that place and Mirán Sháh.

Section III.—The Idak beds form a flat broad anticlinal, which is mostly hidden under the Shamalara plain, between Idak and Shinkai, where they are seen to dip conformably under the upper nummulitic band of limestone, and this is followed normally by the lower and upper siwalik beds, which disappear finally under the Bannu plain.

On the existence of Lower Gondwanas in Argentina, by DR F. KURTZ[1]; *translated by* JOHN GILLESPIE.

I. INTRODUCTION.

As long ago as 1875, Dr. Luis Brackebusch had described a fossiliferous formation which occurs at Bajo de Velis, and on which he has written several papers. He says[2]: "Having received from Mr. D. G. Avé Lallemant some interesting data on the existence of fossiliferous shales in the Cautana valley, I proceeded to that locality, and was not a little surprised to find some fossiliferous beds at Bajo de Velis (about a league from the entrance to the Cautana valley). This exceedingly interesting find detained me a couple of days, and I ascertained that these beds, which consist of conglomerates and argillaceous shales, had only a small vertical and horizontal extent and were unconnected with the high cliffs of the Cautana valley; they form old lake deposits in which a large quantity of plant remains have been inclosed . . . there are no animal remains found in this place." The fossils which Dr. Brackebusch sent to Dr. A. Stelzner are too badly preserved for determination, and consist solely of casts of wood.

Later on, a resident of the place, Sr. Lucio Fúnes, quarried slate for a church at Bajo de Velis, and Sr. Bonaparte, who superintended the work was the first who discovered well-preserved fossil plants, amongst them *Neuropteridium validum*, Feistm., and *Sphenozamites multinervis* non-spec. Señor Bonaparte presented the collection to Sr. D. Gualterío G. Davis, Director of the Meteorological office of Argentina, who handed them over to me for description. In 1883 Señor D. Francisco P. Moreno, Director of the Museo de la Plata, added to this collection from Bajo de Velis, which has enabled me to establish the age of the fossiliferous shales of that locality.

In describing these plants, I have followed the system adopted by W. Ph. Schimper and A. Schenk (in the 2nd part of the Handbuch der Palæontologie by K. A. von Zittel).

II. DESCRIPTIVE PART.

Dr. Kurtz describes 8 species, amongst which there are 3 new species or rather varieties of well-known Gondwana fossils.

III. SUMMARY.

The fossil flora of the argillaceous shales of Bajo de Velis, as far as known at present, consists of the following species:—

Neuropteridium validum, Feistm.
Gangamopteris cyclopteroides, Feistm.
Equisetites Morenianus, Kurtz.
Sphenozamites multinervis, Kurtz.
Noeggerathiopsis, Hislopi (Bunb.) Feistm.
N. Hislopi, Feistm. var. *subrhomboidalis*, Feistm.
N. Hislopi, Feist. var. *euryphylloides*, Kurtz.

[1] Published in the Revista del Museo de la Plata, Vol. VI, p. 117 ff.

[2] Boletin de la Academia Nacional de Ciencias (Córdoba), Vol. II, 1875, p. 188; quoted by Dr. A. Stelzner in Beiträge zur Geologie und Palæontologie der Argentinischen Republik, part I, 1885, pp. 75-76.

All these species are new to Argentina, and partly also to science in general. The small number of specimens collected does not enable us to form an idea as to the relative frequency of the various species, but nevertheless it is apparent that the commonest form met with is *Noeggerathiopsis.* A similar flora is found at the Cape of Good Hope (Ekka-Kimberley beds), in Peninsular India (Kaharbari beds), in Australia (Newcastle beds, Bacchus-marsh sandstone), and in Tasmania

Kaharbari beds (India).	Bajo de Velis (Province De San Luis, Argentina).	Ekka-Kimberley beds (Cape).
Neuropteridium validum, Feistm.	Neuropteridium validum, Feistm.	......
Glossopteris communis, Feistm.		
G. indica, Fstm. . . .		
		Glossopteris Browniana, Brongn.
G. damudica, Fstm. . .		
G. decipiens, Fstm. . .		
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides, Fstm.	
G. cylopt. var. attenuata, Fstm.		Gangamopteris cyclopteroides var. attenuata, Fstm.
G. cyclopt. var. areolata, Fstm.		
G. cyclopt. var. subauriculata, Fstm.		
G. buriadica, Fstm.		
G. major, Fstm.		
G. angustifolia, McCoy.		
Sagenopteris (?) Stoliczkana, Fstm.		
Schizoneura gondwanensis, Fstm.		
Sch. cf. Meriani Schimp .		
Vertebraria indica, Royl. .		
	Equisetites Morenianus, Kurtz.	
Glossozamites Stoliczkanus, Fstm.		
	Sphenozamites multinervis, Kurtz.	
Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.	N. Hislopi var. subrhomboidalis, Fstm.	
	N. Hislopi var. euryphylloides, Kurtz.	

(Mersey coalfield). Of all these floras, that of the Kaharbari beds of the lower Gondwanas in India is closest related to the specimens found at Bajo de Velis, as may be gathered from the accompanying table, which contains a comparison of the various floras mentioned above.

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Sphenopteris lobifolia, Morr.		
S. alata Brongn. et var. exilis, Morr.		
S. germana, McCoy.		
S. hastata, McCoy.		
S. plumosa, McCoy.		
S. flexuosa, McCoy.		
Glossopteris communis, Fstm.		Glossopteris communis, Fstm.
G. Browniana, Brongn.		G. Browniana, Brongn.
G. parallela, Fstm.		
G. linearis, McCoy.		
G. gangamopteroides, Fstm.		
G. ampla, Dana.		G. ampla, Dana.
G. reticulum, Dana.		
G. elongata, Dana.		
G. cordata, Dana.		
G. spathulato-cordata, Fstm.		G spathulato-cordata, Fstm.
		Gangamopteris cyclopteroides, Fstm.
		G. cyclopt. var. attenuata, Fstm.
		G. cyclopt. var. subauriculata, Fstm.
	Gangamopteris angustifolia, McCoy.	Gangamopteris angustifolia, McCoy.
	G. obliqua, McCoy.	G. obliqua, McCoy.
	G. spathulata, McCoy.	G. spathulata, McCoy.
Gangamopteris Clarkeana, Fstm.		
Caulopteris (?) Adamsii, Fstm.		
		Tasmanites punctatus, Newt.
Phyllotheca australis, McCoy.		Phyllotheca australis, McCoy.
Vertebraria australis, McCoy.		
Podozamites elongatus (Morr.), Fstm.		
		Noeggerathiopsis Hislopi, Fstm.
Noeggerathiopsis media (Dana), Fstm.		

Kaharbari beds (India).	Bajo de Velis (Province De San Luis, Argentina).	Ekka-Kimberley beds (Cape).
Carpolithes Milleri, Fstm. Euryphyllum Whittianum, Fstm. Voltzia heterophylla, Brongn.		
Samaropsis sp.		

The following may be deduced from this table with regard to the fossil plants of Bajo de Velis :—

Neuropteridium validum, Fstm., is found in the Kaharbari beds of Bengal where it represents one of the most frequent and most characteristic types. It is noteworthy that this beautiful fern is confined to one horizon only (sandstone beds) of Bajo de Velis.

Gangamopteris cyclopteroides, Fstm., (5 varieties) and 4 other species are the commonest and predominating forms which occur in the Talchir-Kaharbari beds; in the next succeeding horizon, the Damuda division, only some small forms of this genus survive, but they disappear completely higher up. In Africa *Gangamopteris cyclopteroides* has been found only in the lower beds of the "Karoo" formation (the "Ekka-Kimberley" beds) and this is the only species of *Gangamopteris* known in Africa. In Tasmania *G. cyclopteroides* has been found with its varieties, *G. attenuata* and *G. subauriculata*, all in the Mersey coalfield. *Equisetites morenianus*, Kurtz, may be compared with the various remains of the families of the *Equistaceæ*, and of the Schizoneuræ found in the Talchir Kaharbari beds, and very probably belongs to the genus *Schizoneura*, which would clear up an important point connected with the Damuda-Panchet system; in Australia the genus *Phyllotheca* is represented in the group of the Schizoneuræ. *Sphenozamites multinervis*, Kurtz, stands isolated and cannot be compared with forms elsewhere.

Noeggerathiopsis, *Hislopi*, Fstm., occurs in the Talchir-Kaharbari beds and in the middle Gondwanas (frequently at Damuda and South Aurunga); in the upper Gondwana (Rajmahal series) no species of *Noeggerathiopsis* exist (although they occur at Tonkin). In Africa *N. Hislopi*, Fstm., is only seen in the Kimberley beds, and in Tasmania the species has been found in the Mersey coalfield.

Bajo de Velis.	Ekka-Kimberley beds.	Kaharbari bed.
Neuropteridium validum, Fstm.		Neuropteridium validum, Fstm.
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides, Fstm. var.	Gangamopteris cyclopteroides, Fstm.
Equisetites Morenianus, Kurtz.		
Sphenozamites multinervis,		

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Brachyphyllum australe, Fstm. (?); cf. Schimper-Schenk, Palæophytologie, pp. 331, 336).		

where it is associated with another species of the same genus, *N. media* (Dana), Fstm. This last and two more species have been likewise found in New South Wales.[1]

The better to compare the relations which exist between the fossil flora of Bajo de Velis and the plants of the other areas, which we have had under consideration, I have compiled a table of the data available.

From the data given in the following table it may be concluded that the fossil flora of Bajo de Velis belongs to the same geological horizon which holds the other 5 plants mentioned, and that its prototype is the flora of the Talchir-Kaharbari beds of the lower Gondwanas. The palæophytologist O. Feistmantel has already discussed at some length the relation which the lower gondwanas, and the strata in Africa and Australia, occupy to the recognized horizons, especially those of Europe, and has arrived at the conclusion that the formations in question belong to the Permian system, that is to say, that they represent the close of the palæozoic group, a conclusion which several Australian geologists have endorsed, and which in my opinion may be generally adopted with reference to the age of the beds in Argentina[2]:—

[1] The genus *Glossopteris*, so abundantly represented in the various strata of the Gondwana system in South Africa, India and Australia, where it appears for the first time in the upper carboniferous strata (Queensland) and rises to the upper Trias or the lower Jurassic ("Jubbulpore group") is completely wanting in America (as also in Europe); *Glossopteris* is chiefly distinguished from the genus Gangamopteris by the existence on its fronds of a median vein, which character is completely absent in *Gangamopteris*.

[2] It must be mentioned here that this view had practically been adopted by the members of the Geological Survey of India some time before Dr. Feistmantel would admit it himself. (Director Geological Survey of India.)

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Gangamopteris (1 spec.).	Gangamopteris (3 spec).	Gangamopteris cyclopteroides, Fstm., cum var. et. 3 spec. alt.

Bajo de Velis.	Ekka-Kimberley beds.	Kaharbari beds.
Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.		N. Hislopi var. subrhomboidalis, Fstm.
N Hislopi var. euryphylloides, Kurtz.		

Up to date we know of three rock-formations in Argentina which have yielded fossil plants. The first is that of Retamito in San Juan, which corresponds to the lower carboniferous (Culm) as Dr. L. Szajnocha [1] has already shown; then follows the flora of Bajo de Velis which has no species in common with the preceding formation nor with the following series. The latter occurs in the neighbourhood of Cacheuta, Challas and Uspallata in Mendoza, at Mareyes in San Juan, and in the Escalera de Famatina in La Rioja. The fossils found at the latter places belong to completely different flora, which Professor H. B. Geinitz has already determined as belonging to the rhætic,[2] a conclusion confirmed by Dr. A. Stelzner [3] and also by Dr. L. Szajnocha[4].

To the same epoch belong the fossil plants, which are found in the Stormberg beds (Upper Karoo) of South Africa; in the Tivoli-Ipswich beds of Queensland; in the Wianamatta-Hawkesbury beds of New South Wales; and in the Jerusalem beds of Tasmania: that is to say, that these fossil plants occur in horizons between the upper triassic and lower jurassic systems. In India the lower beds of the Rájmahál series (Upper Gondwanas) correspond more or less to the rhætic system.

In the following table I have arranged the plant-bearing beds of Argentina according to their geological horizons:—

Series of beds at Cacheuta, Challas, Uspallata, Marayes, Escalera de Famatina.	Rhætic.
?	Trias.
Bajo de Velis series.	Permian.
?	Upper carboniferous.
Retamito series.	Lower carboniferous (Culm).

[1] Revista, Vol. VI, p. 119; see also Sts. Ber. Kais. Akad. d. Wissensch. Wien, Vol. C, pt. 4, p. 203 (Dir., G. S. I.).

[2] Ueber rhætische Pflanzen und Thierreste in den Argentinischen Provinzen La Rioja San Juan und Mendoza: 1876 (Palæontographica Suppl. III.).

[3] Beiträge zur Geologie und Palæontologie der Argentinischen Republic, I: 1885, pp. 68-82.

[4] Ueber fossile Pflanzenreste aus Cacheuta in der Argentinischen Republic. Sitz. Ber. Kais. Akad. Wiss. Wien., Vol. XCVII, pt. 1, 1888, pp. 219-245.

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Noeggerathiopsis (1 spec.).		Noeggerathiopsis Hislopi, Fstm.

Note by the Director, G. S. I.—The evidence afforded in the above paper has such a strong bearing on the age and relations of the most important of all our rock-formations of India, namely the coal-bearing Gondwanas, that it appeared advisable to have it translated from the Spanish original, which has been ably done by Mr. John Gillespie, to whom our acknowledgments are due.

One of the chief points of interest in connection with the discovery of Gondwana plants in Argentina lies in the fact that there we have an unquestionable lower carboniferous series (Retamito) in the neighbourhood of which (and probably unconformably to it) a series of beds is found, which contains well known lower Gondwana species of plants, thereby limiting the geological range of the lowest beds of it, at all events to upper carboniferous at most, which is a further confirmation, long ago and independently arrived at by the authors of the "Manual" (1st edition) and generally adopted by the Geological Survey of India.

Notes from the Geological Survey of India.

I. *Central India, Rewah.*—Mr. Oldham with Mr. Datta have continued their surveys in Rewah, and some of the results of their work have already been noticed in my annual report and in the "Notes," Records, part 2; with regard to the Vindhyans and underlying rocks no specially new facts have come to light; but, on the other hand, Mr. Oldham has latterly been engaged in the survey of a patch of Gondwanas, which contained several rather fair coal-seams, though few over three feet in thickness. The total extent of the surveyed area of the coal-measures is about 200 square miles, and it is situated east of the Mohan river, shown in sheet 476 of the Rewah survey.

Near their western limit they are covered by red ferruginous sandstones and shales, whose extent has not been determined. The Barakar age (already determined correctly by Mr. Smith) is clearly shown by the fossil contents, amongst which are *Vertebraria*, *Glossopteris*, *Schizoneura*, etc. Two coal-seams of 6 feet and 5 feet 6 inches thickness were found by Mr. Oldham; the former is 1½ miles south-west by west of Ujeini, the latter, 2 miles north of Amlia, both places near the eastern edge of the standard sheet 476.

II. Madras.—Mr. Middlemiss continued his researches in the Salem district and reports in February.

(1) *Magnesite and ultra-basic rock of Valaiyapaddi.*—The magnesite is present in very small quantities. The rocks associated with it entirely resemble those at the north-west end of Kanjamallai, so far as their appearance in the field goes. Forming a long low ridge, running east and west from Valaiyapaddi, there are interesting examples of the above type in close association with a very acid rock, namely, a coarse graphic granite composed almost entirely of pink orthoclase and quartz. Both rocks are intrusive among the basal gneisses of that area in parallel lines. Some good instances of this are to be found west of Valaiyapaddi. The graphic granite was probably intruded last.

(2) *Charnockite, south of Salem.*—Between Muttu Kalipatti and Salem on the Namakal-Salem road a great exposure of charnockite occurs. From its position, strike, and general appearance it is a continuation of the Shevaroy Hills massif.

(3) *Chalk Hills.*—The final few days spent at the Chalk Hills enabled me to secure some "camera" sketches and photographs. As a whole, the aspect of each magnesite area is that of a series of concentric ellipses (roughly speaking) of rocks of varying composition and basicity. At the centre of each area occurs the chromite in veins among the dunite and serpentine; surrounding this is a paler dunite zone (almost pure olivine, or partly or wholly converted into magnesite). Surrounding this again is a small ring of rocks containing olivine and pyroxene with sometimes biotite. Surrounding this at certain points come rocks like the last, but with felspar and quartz in small quantities. Finally, surrounding the whole area come great ridges of hornblende-garnet rocks set among and with the ordinary gneisses of the country.

(4) *Corundum localities, Coimbatore District.*—The corundum localities visited in Coimbatore embraced Selengapalaiyam near Kavanthapatti where the mineral is only sparingly found and picked up from the surface after heavy rain. It is similarly found at Gopichettipalaiyam in one small field. The locality of Siva Mallai is the best that I have yet seen. The mineral is regularly worked for and occurs as large hexagonal prisms scattered about in an extremely coarse biotite granite with pink felspar. The latter follows along the north-west side of a range of low gneiss hills, a continuation of the Siva Mallai. The corundum is chiefly found on the margins of the granite veins.

III. Baluchistán.—During February Mr. Smith examined the high range between the Lúni plain and the Zhób territory. This range is apparently formed of massive jurassic limestone, containing ammonites; its thickness is very great, and in the Wat pass, which leads through the centre of the range, it is quite 2,000 feet, all within sight, and the base is not exposed.

This grey, massive limestone is overlaid by the neocomian belemnite beds, consisting of yellowish to pink, light green and white shaly limestones and shales,—conformably apparently. The entire area near Mekhtar is formed of these beds, which yielded belemnites in abundance besides some ammonites.

This neocomian horizon is overlaid by a great series, which Mr. Smith was enable to divide further, but which seems to have varied a good deal lithologically; the middle of the series apparently contained nummulitic limestone beds, and the uppermost beds were capped by the white nummulitic limestone of the Spintangi

beds. Some of the beds of this great series appear to be derived from volcanic material, and even basaltic rock was met with.

There can be little doubt but that this sequence of beds represents the great belt of strata, which extends from south of Hindu Bágh, north of the Loralai hills along the southern side of the Zhób valley, and which show such a well pronounced flysch character. The lowermost beds are upper cretaceous, whilst the whole lower and middle nummulitic division of the tertiary system is represented.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

CALCUTTA;
The 1st August 1895.

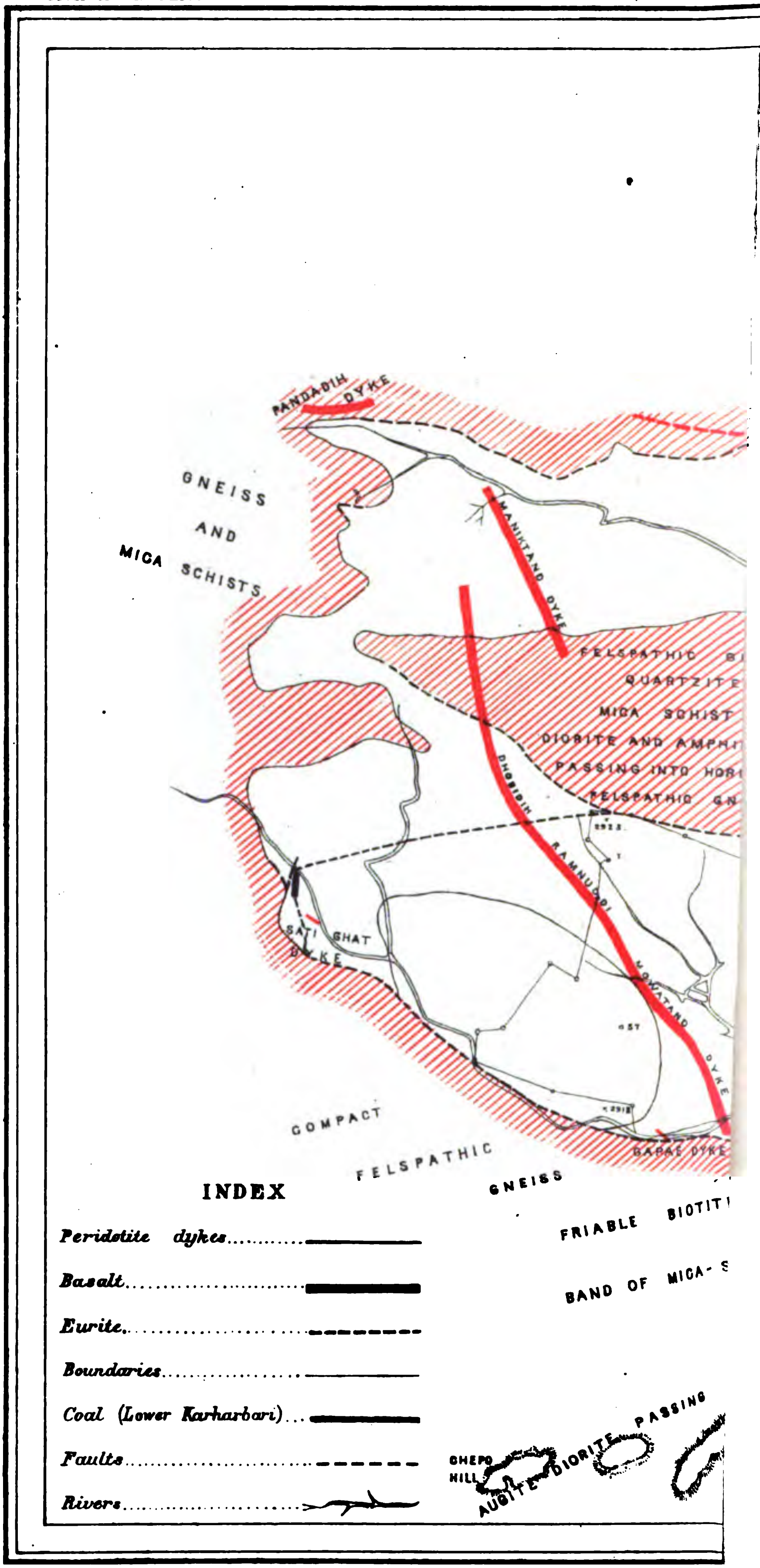
PANDADIH DYKE
GNEISS AND MICA SCHISTS
MANIKTAND DYKE
FELSPATHIC
QUARTZITE
MICA SCHIST
DIORITE AND AMPH
PASSING INTO HOR
FELSPATHIC GN
DHOBIDIH
RAMNUDDI
MONATAND
DYKE
SATI GHAT DYKE
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Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig 6.

ROCKS FROM THE GIRIDIH COALFIELD.

Photographs by W. J. Simmons & T. H. Holland.

Photo etching.

Survey of India Offices, Calcutta, October 1895

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.]	1895.	November.

On the Igneous Rocks *of the* Giridih (Kurhurbaree) Coalfield *and their* Contact Effects. *By* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India*, and WALTER SAISE, A.R.S.M., D.Sc., F.G.S., *Manager, East Indian Railway Company's Collieries, Giridih*. (With map., pl. 4, and two wood-cuts.)

CONTENTS.

I.—INTRODUCTION.

1. The dyke-rocks of the Giridih coalfield have been mentioned and mapped by Mr. T. W. H. Hughes, late Superintendent, Geological Survey of India, in a memoir published in 1868[1]. The 15 dykes described by that author were classified as (1) dioritic traps, (2) compact felspathic traps, and (3) micaceous traps. Mr. Hughes

[1] *Mem. Geol. Surv. Ind.*, Vol. VII, p. 209.

has also briefly referred to the crystalline rocks which fringe the whole coalfield and form also two faulted inliers amongst the Talchirs in the north-west corner.

2. Later investigations facilitated by widely-extended subsequent mining operations have enabled us to add many facts concerning the relations and field characters of these dykes, whilst microscopic and chemical examination in the laboratory of the large number of specimens collected has revealed many additional facts, which appear to be of both local and general interest. We gratefully acknowledge the help most generously given in many ways by Mr. T. H. Ward, F.G.S.

II.—GENERAL STRATIGRAPHICAL CHARACTERS OF THE COALFIELD.

3. The Giridih (Kurhurbaree) coalfield consists of a small patch of strata of Barakar and Talchir age, measuring 11 square miles, and preserved between three nearly parallel faults, which trend east and west. The Barakars appear at the surface for over 7 square miles and the Talchirs for over 3½ square miles, the remainder ⅞ square miles, being inliers of crystalline rocks.

Barakar Stage.

4. The Barakars, having a total thickness of nearly 1,000 feet, include at the top several great seams of inferior coal (the *hill seams*) with coarse sandstones, conglomerates and dark felspathic grits, lying on 500 feet of light-grey, coarse sandstones and conglomerates containing well-rounded boulders of quartzite, with dark grey grits, and a few bands of shale or impure coal. Underneath these beds occur 150 feet of grits in which the two main seams of Kurhurbaree coal occur (Kurhurbaree upper and lower seams).

Talchir Stage.

5. The Talchirs, lying below the Barakars, consist of friable, greenish and yellowish sandstones overlying yellow and blue shales, which weather in a very characteristic fashion into nodular masses and acicular fragments. Underneath these shales occurs the well-known boulder-bed. The total thickness of the Talchirs is about 150 feet.[1]

III.—THE IGNEOUS ROCKS.

6. According to their geological age, the igneous rocks may be grouped into—

(*a*) those which were intruded into the crystalline series before the deposition of the Talchir group, and

(*b*) those which have been intruded subsequent to that period, and, probably, subsequent to the formation of the youngest Damuda rocks in Bengal.

7. The time which elapsed, therefore, between these two sets of intrusions was at least as great as that required for the deposition of the Damuda series. We shall give below (paras. 17, 18 and 30) the evidences which suggest that some of the former group of intrusive rocks (*Pre-Damuda*) were subjected to statical metamorphism

[1] Detailed descriptions of the stratigraphy of this area will be found in the memoirs by Mr. Hughes (*Mem. Geol. Surv. Ind.*, Vol. VII (1868), p. 209), and in a paper recently published by one of us (Saise, *Rec. Geol. Surv. Ind.*, Vol. XXVII (1894), p. 86). Reference to previous literature on the same subject will be found in these papers.

at the time of the intrusion of the oldest of the latter group (*Post-Damuda*), and subsequently suffered from the results of dynamical metamorphism, probably when the main faults of the field were developed.

(a) PRE-DAMUDA IGNEOUS ROCKS.

8. The crystalline rocks, which have already been mentioned, have been invaded by igneous rocks whose pre-Damuda age is assumed principally from negative evidence. They can be traced up to the boundary faults in several places, but are never found within the limits of the stratified area; they are assumed, therefore, to be older than the boundary faults, and, with less certainty, than the Damuda strata forming the coalfield. The dyke of eurite on the north of the field marks the boundary for a considerable distance, the plane of the dyke-face forming apparently a line of low resistance along which the fault has developed.

9. Neglecting the question of the origin of the ordinary crystalline gneisses and schists, the rocks which form well-defined dykes and are considered to be of immediate igneous origin are—

(1) Diorites.
(2) Granites and Eurites.

(1) DIORITES.

10. By their resistance to the weather, the diorites generally rise as small hills from amongst the crystalline series. Similar rocks, in which, in hand-specimen, hornblende is always a prominent constituent, occur as dykes in various places amongst the crystallines of Chota Nagpore, the Sonthal Pergunnahs and Raniganj, but never breaking through the sedimentary rocks.

Origin of the diorites.

11. The way in which these have developed from an original pyroxene-plagioclase rock is very easily demonstrated in almost every one of these masses; but the secondary changes which have been brought about by both statical and dynamical metamorphism show some interesting variations in the different localities. On the north and east of the coalfield, for instance, the development of hornblende from the original pyroxene, and of a granulitic structure from an original granitic one, is accompanied by the production of large quantities of scapolite. In these rocks a prominent constituent is apatite. On the south of the coalfield, on the other hand, the augitic rocks pass into hornblende-granulites and even hornblende-schists, which are entirely devoid of scapolite. It is very interesting to note that in these rocks, which do not give rise to scapolite, there is, unlike those of the northern margin, not a trace of apatite.

Werneritization.

12. In the rock described in 1875 by Brögger and Reusch[1] as *gefleckter Gabbro*, and in which the apatite veins of Oedegaarden occur, Professor Judd has traced the changes by which plagioclase-felspar has been transformed into scapolite. Liquids under pressure and containing chlorine in some form or other produced

[1] *Zeitschr, d. d. geol. Ges.*, Vol. XXVII, p. 646.

A 2

cavities by solution along the twin-planes in the felspar, and these cavities became filled with supersaturated solutions of sodium-chloride. Following these changes, which form a part of the statical metamorphism[4] to which the rock has been subjected, crushing of the mass has produced a granulitic structure accompanied by the conversion of the mixture of plagioclase and sodic chloride into crystals of scapolite[5]. In the hornblendic rocks on the north-east boundary of the Giridih coalfield, in the neighbourhood of Paharidih and Mongrodih, we have a most striking illustration of the development of scapolite from plagioclase by the successive effects of statical and dynamical metamorphism similar to those which have been so beautifully traced in the celebrated *Apatitbringer* of Oedegaarden in Norway by Professor Judd.

Mineral composition of original rock.

13. The original rock contained both monoclinic and rhombic pyroxenes. The former appears under the microscope as colourless plates with a feeble attempt at an ophitic arrangement around the felspars. These are invariably changed at their margins into granules of hornblende. The rhombic pyroxene occurs in minute granular aggregates darkened by the products of schillerization and forming at the junctions with felspar reactionary fringes which are composed of radially arranged blebs of a colourless mineral and hornblende.

Statical metamorphism of the plagioclase.

14. The plagioclase felspars are invariably crowded with minute colourless liquid inclusions arranged along the twin-planes (see plate fig. 3). As the crushed rock gave, with nitric acid and silver nitrate, unmistakeable reactions for a chloride, we concluded that these inclusions, like those in the Oedegaarden rock, are solutions of sodic chloride.

Accessory constituents.

15. Amongst the accessory constituents, crystals of black iron ores, garnet which is of secondary origin, apatite, quartz and calcite are found in small quantities.

Dynamical metamorphism of the rock.

16. This compact rock with *granitic* structure, composed almost wholly of *pyroxene* and *plagioclase*, and in which the effects of statical metamorphism are so strikingly shown, passes within a short distance along the same dyke into a distinctly foliated *granulitic* rock, in which *hornblende* and *scapolite*, by far the most abundant constituents, are mixed with a granulitic aggregate of *clear* felspar and quartz. Not the least interesting features in the rock are the patches which have escaped the effects of the dynamo-metamorphism. In these the old granitic structure is preserved and the felspars still clouded with inclusions, whilst scapolite is absent.

Paragenesis of apatite and scapolite.

17. The frequent close association of apatite and scapolite in Norway, Canada and elsewhere, naturally reminds us of the remarkable apatite-bearing peridotite which breaks through the Damuda strata in the immediate neighbourhood of the scapolite-bearing rocks of this area. According to the analyses of Waage, quoted by Brögger and Reusch[6], the apatite of Oedegaarden contains from 3 to 5·8 per cent. of chlorine. In the Giridih area also the apatite of the peridotite is a chlor-apatite. We have

[4] On statical and dynamical metamorphism: *Geol. Mag.*, Dec. III, Vol. VI (1889), p. 243.

[5] *Min Mag.*, Vol. VIII (1889), p. 186.

[6] *Loc. cit.*, p. 674.

thus a suggestion for the origin of the chlorine, which has in both cases brought about the preliminary changes necessary for the formation of scapolite from plagioclase in a previously-formed pyroxene-felspar rock, such as that at Mongrodih and the *geflecter Gabbro* of Oedegaarden.

Geological age of the scapolite.

18. Accepting this explanation, the formation of the scapolite may have commenced at any time after the deposition of the Damuda rocks, which we shall show to be the oldest limit of the peridotite intrusion (see para. 29—32; also Holland, *Rec. Geol. Surv. Ind.*, vol. XXVII (1894), p. 132). For the subsequent movements of the rocks which gave rise to the granulitic and foliated structures, the Rajmahal eruptions which fissured the country in all directions must have been sufficient to account for the younger faults and the small amount of crushing which has produced a rough foliation approximately parallel to the main faults. We consider that the intrusion of the peridotite, the production of the leading faults, and the werneritization of the pyroxene-felspar rocks occurred in close succession, at a period not far removed from the time of the deposition of the Panchet rocks.

Uralitisation.

19. The production of hornblende by paramorphism of the augite is the most conspicuous amongst the secondary changes which have been produced in the pre-Damuda pyroxene-plagioclase intrusions. There are two principal types of this change: (1) At Bonkhoonju, a small peak west of the Oosri nuddi and north of the coalfield, hornblende develops with crystallographic parallelism to the porphyritic augite from which it is derived, and the rocks have suffered comparatively little from crushing. (2) In Chepo hill and near Gujiadih, on the southern border of the coalfield, where the band of dioritic rocks runs east-north-east and west-south-west, parallel to the general strike of foliation in the crystalline series, the hornblende has formed in isolated crystals in the augite without definite crystallographic relations to the latter, whilst the rocks themselves are sometimes so crushed and foliated that they become fissile hornblende-schists.

Uralitization at Bonkhoonju.

20. (1) In the rocks from Bonkhoonju hill the large phenocrysts of augite are darkened with schillerization plates, and the change to hornblende takes place along the margins of the crystals, extending inwards to varying degrees. The hornblende selvages so formed show optical continuity over considerable areas, the vertical crystallographic axis of the mineral generally coinciding with that of the augite undergoing the paramorphic change.

Without scapolite.

There are again two types of these rocks. In one lot the large augites show a lustre-mottling in the hand-specimen, whilst the felspars retain their original long prismatic shapes, and are darkened by inclusions. In this type there are patches of biotite generally with a lump of black iron-ore in the centre of each patch, and a granular pleochroic rhombic pyroxene which occurs in conspicuous quantities. In the other type, the felspars show a granulitic structure, with either clear scapolite crystals or patches of a grey fibrous material which strongly resemble the decomposition-products of scapolite. Biotite occurs irregularly but always intimately associated with the hornblende from which it has possibly been derived. Sphene and apatite are scattered irregularly through all these rocks.

With scapolite.

21. (2) The Chepo hill mass shows generally a more advanced stage in the uralitization to hornblende, the crystals springing up at irregular intervals in the augite crystals, and showing little regard for the optical orientation of their neighbours. Epidorites and even well-foliated hornblende-schists occur along the same band of rocks at Gujiadih. Sphene and colourless epidote are represented, but apatite (unlike the Bonkhoonju rocks) is noticeably absent; the acicular crystals scattered through the felspar shew a much higher double refraction than that of apatite.

Uralitization at Chepo and Gujiadih.

(2) EURITES.

22. Besides the masses of binary granite which occur at several places amongst the felspathic gneisses, there are two large dykes of eurite—one running close to the northern boundary fault, and for some distance along the fault (see para. 8), and the other running in a parallel direction on the southern boundary from a point a little to the south of the junction of the Komaljore and Suni nadis to a point where the latter crosses the fault.

23. The eurite is a dark-green compact rock exhibiting a fracture which is conchoidal, except where interrupted by the numerous inclusions of hornblende-granite. Quartz in small granules is scattered through the grey microcrystalline matrix, and sometimes occurs in larger fragments which show crystal outlines. The absence of ferro-magnesian silicates amongst the phenocrysts is a very noticeable feature. The patches of coarse-grained granitic material, giving a glomero-porphyritic structure to the rock, contain considerable proportions of plagioclase with small quantities of hornblende. The whole rock has been brecciated and the pieces re-cemented with granular quartz.

Structure of the eurites.

(b) POST-DAMUDA INTRUSIONS.

24. The dykes which break through the stratified rocks of Damuda age are of two very distinct types:—

(1) A group of mica-peridotites remarkable for the amount of apatite they contain, and,

(2) Large dykes of basalt, younger than the foregoing set and probably the underground representatives of the Rajmahal lava-flows.

Dykes of the former class can generally be identified with the compact felspathic and micaceous traps of Mr. Hughes, whilst the latter are referred to as dioritic traps by the same author.

(1) PERIDOTITES.

25. The rocks which have been generally known to previous wrtiers as "mica traps" occur in this and in most of the Bengal coalfields in the form of dykes and intrusive sheets with very marked characteristics. The dykes are generally narrow (3—5 feet)

Characters of Peridotite intrusions.

and at the surface are always decomposed to a soft buff-coloured crumbling earth, which is often vesicular and contains remnants of partially-decomposed bundles of mica. Traced below the surface in the colliery workings, these dykes are seen to send out ramifying apophyses into the surrounding coal and sandstones, and in some places they thicken out into boss-like masses, or even spread out in wide sheets along the bedding planes, coking the coal with the production of beautiful columnar structures, baking the shales, and partially fusing the felspathic sandstones into compact rocks, which sometimes show structures in section like those seen in rhyolites (para. 53).

26. As compared with other igneous intrusions of this area, the results of the widely-extended results of contact-metamorphism produced by the irruption of these "mica traps" everywhere appear to a very marked degree. Taking this fact into consideration with the length of such narrow dykes in the different coalfields, it seems natural to suppose, as previously suggested by one of us,[7] that the igneous material was injected in a very mobile condition at an exceptionally high temperature.

Microscopic characters of the Peridotites.

27. The colliery workings, besides enabling us to trace the various ramifications of these intrusive rocks, have exposed at greater depths masses of the rock which have suffered very little from secondary decomposition. The microscopic characters, which have been described in detail by one of us,[8] prove it to be of a type quite unique amongst the remarkable group of peridotites. A character which seems to be constant throughout the coalfield is the most exceptional quantity of apatite amongst the constituents of this peridotite, amounting in the freshest specimens obtained to as much as 11·5 per cent. of the rock. In these specimens which were obtained from the boss-like expansion in No. 7 Jogitand shaft, the apatite is accompanied by biotite, olivine, magnetite, chromite and a grey base which is considered to be the vitreous residue of the rapidly cooled and imperfectly crystallized magma. In other places augite and anthophyllite are amongst the ferro-magnesian constituents. Whilst the corresponding rocks in the Darjeeling coal-measures, where, by the way, apatite is subordinate in quantity, are sometimes composed entirely of crystals, those of the Giridih coalfield are, so far as our researches show, always hemicrystalline like the kimberlites described by Carvill Lewis in the Gondwana rocks of South Africa. As might be expected, the central portions of the larger masses are always coarser in grain than the more rapidly cooled selvages.

Decomposition of the Peridotites.

28. Subterranean circulating waters, in which the proportions of carbonic and to a less extent sulphuric acids are increased by the slow oxidation of the pyritous coal, bring about secondary changes in the rock constituents with the production of serpentine, followed invariably by rhombohedral carbonates and sometimes by secondary quartz. At the surface, oxidation of the iron compounds and removal of the alkalies and alkaline earths in solution leave a buff-coloured or rusty soft clay in which mica seems about the last mineral to lose its original characters.

[7] Holland. *Rec. Geol. Surv. Ind.*, Vol. XXVII, p. 133.
[8] Holland. *Loc. cit.*, p. 129.

Distribution and Geological age of the Peridotites.

29. Dykes of the mica-peridotite are found cutting through the hill seams and the Kurhurbaree upper seam; but it is in the lower seam that the intrusions are most numerous, and here they spread out in great sheets destroying the coal over large areas. As might be expected the greater pressure at lower depths forced the molten material along the bedding planes of the least resisting rock, namely, the coal.

30. On the accompanying map we have indicated the position of 19 peridotite dykes so far as they are traceable at the surface. These show a general tendency to run east and west. Whilst they cross the older faults in the lower seam they do not break through the boundary faults, as is the case with the younger basaltic intrusion. The intrusions are therefore younger than some of the faults *within* the coalfield but are probably older than the *boundary faults* of the field. This agrees with a suggestion we have already made that the statical metamorphism of the pre-damuda pyroxene-felspar rock of the adjoining area occurred at the time of the intrusion of this chlor-apatite bearing peridotite and the subsequent movements which changed the former rock into a hornblende-scapolite granulite brought about the great faults, which dropped the Giridih coalfield into its present position. It is certainly very significant to note with reference to this suggestion that where the original pyroxene-felspar rock was furthest removed from these peridotite intrusions, as at Chepo, there is not the slightest sign of scapolite in the foliated hornblendic rocks.

31. One of the dykes only (the Buriadih dyke, No. 2 on list) passes into the crystallines; and the boundary of the coalfield at this point is a natural one, not faulted.

32. The highest strata amongst the Damudas at Giridih are cut by the peridotite dykes. Passing to the Raniganj coalfield we find the youngest Damuda beds there, namely, the Raniganj-stage, are also invaded by this rock; but beyond this we have no reliable evidence for fixing with greater precision the *oldest* limit of the intrusion. The *youngest* limit is determined by the basalts which, following Dr. Blanford, we regard as Rajmahal in age. We have thus a peridotite intrusion probably contemporaneous with the formation of some part of the Panchet group.

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33. *Catalogue of the Mica-peridotite dykes in the coalfield.*

No.	Name of dyke.	Direction.	Thickness.	Remarks.
1	Dandidih	NW—SE	3 feet	
2	Buriadih	NW—SE	1 foot	No. 6 of Hughes.
3	Chunka	NW—SE	2 feet	
4	Khandiha	NNW—SSE	2 "	No. 8 of Hughes.

No.	Name of dyke.	Direction.	Thickness.	REMARKS.
5	Kopa	NNW—SSE	2 „	No. 15 of Hughes.
6	Baniadih . . .	NW—SE	1 foot	
7	Bungalow pit Buniadih .	W—E	1½ „	No. 10 of Hughes.
8	Domahani . . .	W—E	1 „	„ 11 „ „
9	Jubilee pit . . .	W—E	6 inches	„ 10 „ „
10	Bhaddoah hill . .	W—E	1 foot	
11	Sariabad . . .	W—E	1 „	
12	Gapae	WSW—ENE	1 „	
13	Satighat . . .	NW—SE	1 „	No. 13 of Hughes.
14	Bittagarha . . .	ENE—WSW	1 „	
15	Jogitand . . .	ENE—WSW	1 „	
16	Jogitand—Lunki . .	WNW—ESE	1—5 feet	No. 5 of Hughes.
17	Chaitadih . . .	WNW—ESE	1 foot	
18	Mowlichooah . . .	N—S	2 feet	No. 1 of Hughes.
19	Birwadih . . .	W—E	1 foot	

(2) BASALTS.

34. The greater thickness and the spheroidal weathering of the hard, black or dark-grey basalts are characters which serve to distinguish without difficulty the dykes of this rock from those of the mica-peridotite with which, within the limits of the coalfield, they are so frequently associated. These dykes sometimes attain a thickness of 100 feet, and yet nowhere has the action of this rock on the strata produced results in any way comparable to the effects of the much narrower intrusions of the mica-periodotite. So far as we know, the basalts never spread as sheets along the bedding planes of the sedimentary strata which have been invaded.

35. Specimens of the basaltic rocks have an average specific gravity of 2·99. Under the microscope they are seen to be composed of *olivine*, partially decomposed with the formation of green and yellow serpentine, *plagioclase felspar* in lath-shaped crystals, *magnetite*, often developed around the felspars, and included by the pale brown *augite*, which is developed ophitically around the crystals of earlier consolidation. There is always a residue of feathery microlites in a hyalopilitic matrix.

Occurrence and geological age of the basalts.

36. The basalts cut through the faults within the limits of the coalfield and strike across the boundary faults into the adjoining crystalline series. Where their junctions with the peridotites have been exposed and examined, it is seen that the

latter rocks are displaced and cut through, proving the basalt to be distinctly younger than the mica-peridotites. (See fig. 1). Seeing they cut across the boundary faults, they may be regarded as younger than the coalfield as a whole.

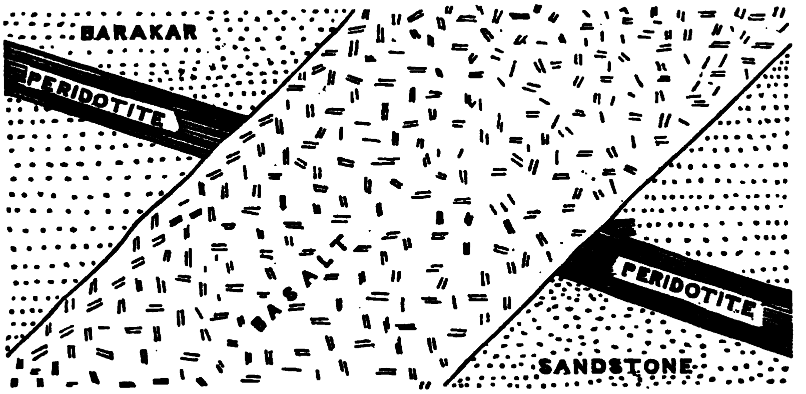

Fig. 1. Plan showing the Baniadih-Kamaljore dyke of basalt crossing the Jogitand-Lunki dyke of peridotite.

Following the conclusions of Dr. Blanford concerning the age of the augitic dykes of the Raniganj coalfield[9] and of subsequent workers in other Bengal coalfields, it seems safe from analogy to consider these basalts to be the dyke representatives of the petrologically similar basaltic outflows of Rajmahal age.

37. The following is a list of the six basaltic dykes mapped :—

No.	Name of Dyke.	General direction.	Thickness.	Remarks.
1	Pandadih . . .	E—W	20 feet.	In the crystallines.
2	Maniktand . .	NW—SE	50 „	No. 14 of Hughes.
3	Dhobidih-Mowatand .	NW—SE	5—100 „	„ 12 „ „
4	Baniadih-Komaljore .	NE—SW	5—100 „	No. 9 „ „
5	Baniadih . . .	NW—SE	30 „	......
6	Kopa-Kabribad .	E—W ESE—WNW	5— 50 „	No. 7 of Hughes.

38. The two sets of intrusive rocks just considered—the mica-peridotites and the basalts—are associated with one another in nearly all the coalfields of Bengal, and we have shown that the more basic eruption has been the first to be intruded. As all workers agree in considering the basalts to be of Rajmahal age, and we have shown that the peridotites are younger than the Raniganj stage, these two sets of intrusions cannot differ very greatly in geological age. But they are nevertheless quite distinct in order of eruption. They are equally distinct in petrological

[9] *Mem. Geol. Surv. Ind.*, Vol. III, pp. 141—149.

characters and mode of occurrence; and we do not see that there is any proof of their having been derived from a common magma, although this has been assumed so frequently during the last two or three years as a necessary premise for explaining the irruption in order of basicity of igneous rocks associated with one another within the limits of comparatively small areas. The older set of intrusions are represented by mica-peridotite as the leading petrological type; they occur in all the coalfields of Bengal from Raniganj to Darjeeling, and are of about Panchet age. In places by the introduction of felspar, these pass into basalts, but of a type which could never be mistaken for the Rajmahal rocks. The younger group of intrusions are basalts with olivine passing into augite-plagioclase rocks; they stretch to considerable distances around Raniganj, and belong to a petrographical province of Rajmahal age. It would be a great convenience if we had some conveniently short nomenclature to express the geological age, geographical limits, and petrological facies of petrographical provinces so marked as these cases presented to us in Bengal.

Relations of the peridotites and basalts.

(3) COMPARISON WITH SOUTH AFRICAN INTRUSIONS.

39. In studying the post-Damuda intrusive rocks of this and the other coalfields of Bengal, it is impossible to overlook the apparent parallelism with the igneous rocks which invade the Karoo system of South Africa. Although the South African beds have not been sufficiently investigated to allow of great precision in correlating the various groups there represented with the Gondwanas of India, the palæontological and lithological characters of the deposits leave no doubt about the Karoo system being homotaxially equivalent to the lower and a portion of the upper Gondwana system in India.

40. The rocks intrusive into the Karoo beds belong to two groups:—

(1) The diamond-bearing peridotite breaking through the Ecca beds and Kimberley shales.

(2) The basaltic rocks which break through the whole series and form contemporaneous lava-flows capping the Stormberg beds.

41. In India we know beyond question that the peridotites are older than the associated basalts. In Africa we only know that they break through the older strata and are not found in the higher beds.

42. In India the basaltic dykes break through the whole of the lower Gondwanas and are considered to be the underground representatives of the Rajmahal lava-flows. The basalts of South Africa traverse in like manner the complete Karoo system from the Ecca stage to the Stormberg beds.[10] Whilst it is not yet possible to fix exactly the position, and especially the youngest limit, of the Stormberg beds, they are certainly not older than the Panchets and are probably not far removed in age from the Rajmahals.

43. Whilst admitting, therefore, that the evidence is but fragmentary, we consider that the facts of stratigraphical distribution and petrological features, so far as they are known, are sufficient to warrant as a tentative conclusion the existence of one, if not two, petrographical provinces of Gondwana age extending from South

[10] Green *Quart. Journ. Geol. Soc.*, Vol. XLIV, (1888), p. 239.

Africa to India. The oldest of these was characterised by peridotites, and these were followed, at a period not far removed, by enormous outflows of basalts and augite-andesites.

IV.—CONTACT-EFFECTS.

44. The intrusions of peridotites and basalts into the Damuda strata have given rise, as already stated, to very marked contact-metamorphism, especially in conjunction with the former group of igneous rocks. The results, as might be expected, are most striking amongst the coals, whilst the sandstones have been hardened by baking and even partial fusion, and the shales merely baked.

1. Contact-Metamorphism of the Coal.

45. Even the narrow dykes of peridotite, where they pass through the coal seams, are bordered with a zone of beautifully columnar coke two or three feet thick on either side of the dyke. The volatile bituminous matter having been driven off, the resulting contraction in the mass produced a columnar structure with injections of thin films of the igneous rock along the cracks.

46. The series of proximate assays given below are of altered coal taken at gradually increasing distances from the margin of the peridotite dyke, and compared in each case with specimens of unaltered coal from the same seam.

Series A.

47. Specimens taken from lower seam, south of No. 7 Jogitand shaft, Giridih coalfield:—

Thickness of peridotite dyke, 4 feet.
Thickness of coked zone, 3 feet 6 inches.

	Numbered from the Dyke outwards.					
	1	2	3	4	5	6
Volatile matter (excluding moisture.)	4·10	4·89	6·40	6·80	15·45	20·71
Fixed carbon . .	64·63	74·36	71·79	80·69	74·31	67·46
Ash	31·27	20·75	21·81	12·51	10·24	11·83
Total .	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, light brown.	Does not cake. Ash, light reddish brown.	Does not cake. Ash, light brown.	Does not cake. Ash, light reddish brown.	Cakes, but not strongly. Ash, light reddish brown.	Cakes strongly. Ash, light brown.

Series B.

48. Specimens taken from lower seam on northern side of No. 7 Jogitand shaft, Giridih coalfield:—

Thickness of peridotite dyke, 3 feet.
Thickness of zone of altered coal, 3 feet.

	NUMBERED FROM THE DYKE OUTWARDS.					
	1	2	3	4	5	6
Volatile matter (excluding moisture).	5·31	4·95	6·71	4·84	8·01	19·10
Fixed carbon . .	71·51	72·84	77·70	83·29	78·72	59·43
Ash	23·18	22·21	15·59	11·87	13·27	21·47
TOTAL .	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake.	Does not cake.	Does not cake.	Does not cake.	Does not cake.	Cakes, but not strongly.

49. An examination of these assays leads to the following general conclusions:—

(1) There is a loss of bituminous matter as the igneous rock is approached.

(2) The fixed carbon at first increases in proportion to the loss of the volatile constituents until close to the dyke the fixed carbon again decreases, which we presume to be due to its oxidation and replacement by inorganic bases.

(3) The ash increases in percentage as the dyke is approached, and this increase is far greater than would be due to the simple removal of volatile matters (*vide infra*, para. 52).

50. These conclusions are more uniformly illustrated by considering the averages of assays of adjacent pairs of samples and compared as follows with a sample of unaltered coal from the same seam:—

Series A.

	NUMBERED FROM THE DYKE OUTWARDS.				
	1 and 2.	3 and 4.	5 and 6.	Two specimens at 4 feet from dyke.	Specimen at 10 feet from dyke.
Volatile matter . . .	4·49	6·60	18·08	22·12	24·70
Fixed carbon . . .	69·50	76·24	70·89	66·60	65·99
Ash	26·01	17·16	11·03	11·28	9·31
	100·00	100·00	100·00	100·00	100·00
	Do not cake.	Do not cake.	Cake.	Cake strongly.	Cakes strongly.

Series B.

	1 and 2.	3 and 4.	5 and 6.	Two specimens at 4 feet from dyke.	Specimen at 10 feet from dyke.
Volatile matter . .	5·13	5·77	13·55	26·40	27·80
Fixed carbon . . .	72·18	80·50	69·08	66·65	66·16
Ash	22·69	13·73	17·37	6·95	6·04
	100·00	100·00	100·00	100·00	100·00
	Do not cake.	Do not cake.	No. 6 cakes slightly.	Cake strongly.	Cakes strongly.

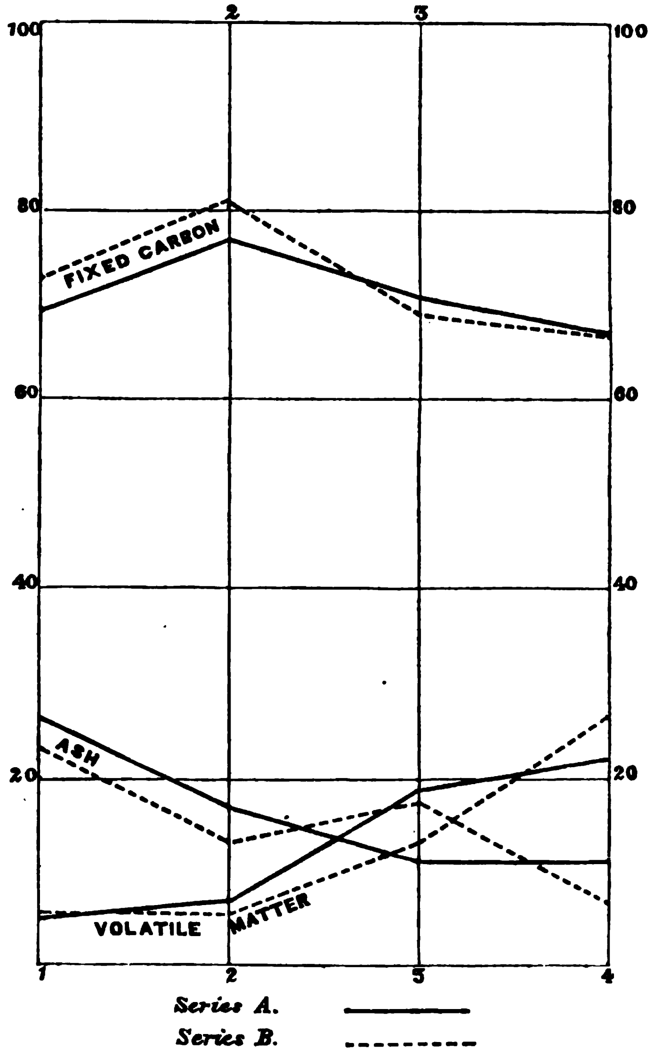

Fig. 2. Diagram showing variation in composition of the coal to a distance of 4 feet from the dyke.

51. The following assays of specimens kindly supplied by Mr. F. J. Agabeg from a coal seam invaded by peridotite in pit No. 2, Cheranpore colliery, Asansol, show a similar series of results :—

	No. 1. Average of 4 samples into which veins of trap have ramified near dyke.	No. 2. Average of 2 samples outside the former group.	No. 3. Unaltered coal from the same seam.
Volatile matter	6·44	11·55	31·40
Fixed carbon	49·37	69·86	58·65
Ash	44·19	18·59	9·95
	100·00	100·00	100·00

52. If the increase in the percentage of ash were due simply to proportionate removal of the volatile constituents, we should expect a maximum in each case as follows :—

Series A :—	13·7	per cent. Ash
„ B :—	8·8	„ „ „
Cheranpore :—	13·2	„ „ „

Whereas we have 31·27, 23·18 and 44·19 per. cent. respectively.

Increase of Ash percentage.

Sir I. Lowthian Bell in discussing the origin of the bases in the "white post" lying above the basalt in Durham colliery considers that bases are sublimated from the highly heated basalt at the time of its intrusion in the molten state.[11] Whilst this may have taken place in the case of our still more highly heated peridotites, we consider that in this particular case the largest portion of the inorganic material has been introduced subsequent to the consolidation of the igneous rock by infiltration of solutions into the coke which is naturally more vesicular where it has lost most of its bituminous matter. The peridotites are all highly decomposed in the small dykes and on the selvages of the larger masses, and the deposition of rhombohedral carbonates and quartz in place of the original olivines is sufficient evidence of the re-arrangement of bases which has been brought about in the rock by secondary causes since consolidation.

CONTACT-METAMORPHISM OF SANDSTONES.

Fusion of the Felspathic sandstones.

53. About the most remarkable amongst the effects of contact-metamorphism are the changes produced in the Barakar sandstones. Hardening of the sandstones is common enough wherever they come within range of the peridotite sheets, but in some places, where the sandstones are felspathic and with partially kaolinised felspars, there has been a partial fusion produced, with the result that the quartz and felspar crystals have been rounded and corroded in bays and inlets like the phenomena so common in the rhyolitic lavas. The glass formed by the fusion is crowded with radially arranged microlites, and generally so strikingly recalls the

[11] *Proc. Roy. Soc.*, Vol. XXIII (1875), p. 543.

appearance of a rhyolite that we found it necessary to reassure ourselves by repeated field examination that we had not by chance sampled a hitherto undetected acid lava-flow. There is no doubt, however, about the nature of the rock with which we are dealing. It can be traced out to sandstones which are merely baked or fritted and thence to the loose characteristic Barakar sandstones with decomposed felspars. The signs of fusion discovered by the microscope are after all only in agreement with other evidences which point to the very high temperature of the peridotite intrusion, and taking this fact in connection with the tendency of this peridotite to spread in sheets amongst the sedimentary rocks, we see an explanation for the beds of hardened sandstone which so puzzled earlier observers that they were often described by the vague term "trappoid sandstones" and have even been considered "traps" —a blunder the more easily made by the field-worker from the way in which these hardened sandstones form ridges running across the country and breaking with a cuboidal jointing so common in trap-flows.

54. It is interesting to note that Mr. Hughes also, as long ago as 1866, explained the occurrence of similar hardened ridges as the result of "trappean action" in the Jherriah coalfied, where they also show a columnar structure.[13]

We have figured and described a slide showing the results of the partial fusion of a sandstone which is associated with the peridotite plexus of Bhaddoah hill (plate I, fig. 6).

V.—SUMMARY OF RESULTS.

55. The igneous rocks of the Giridih area may be divided into two groups:—

1st.—*Eurites* and *pyroxene-plagioclase* rocks which were intruded amongst the crystalline rocks before the deposition of the strata of the Damuda epoch.

2nd.—*Mica-peridotites* and *basalts* which have invaded the Damuda series.

56. The pyroxene-plagioclase rocks have undergone two sets of changes. On the north of the coalfield they have passed into *uralite-diorites* and *epidiorites* with the formation of much *scapolite*. On the south they have changed into epidiorites, and hornblende-schists *without* the development of scapolite.

57. The *statical metamorphism* of the plagioclase in the plagioclase-augite rock probably took place at the time of the intrusion of the apatite-bearing mica peridotite, and the subsequent *dynamical metamorphism* attended with the development of scapolite was probably contemporary with the formation of the great boundary faults of the coalfield.

58. The *mica-peridotites* are remarkable for the large quantities of *apatite* they contain, sometimes amounting to over 11 per cent. These rocks are post-Damuda though pre-Rajmahal in age. They form long narrow dykes in the younger strata and spread out in wide sheets at greater depths.

59. The *basalts* occur in wider dykes breaking across the peridotites and are regarded as the underground representatives of the Rajmahal lava-flows.

60. There is a striking parallelism between the post-Damuda intrusions of Bengal and those invading the Gondwana rocks of South Africa, where the diamond-bearing peridotite of Kimberley is succeeded by enormous outflows of basalt.

61. The effects of *contact metamorphism* of the mica-peridotite are far more

[13] *Mem. Geol. Surv. Ind.*, Vol. V, p. 323.

striking than those of the basalts, although the latter form very much thicker dykes. The former rock we conclude was introduced at a very much higher temperature.

62. Amongst the contact effects the partial fusion of the felspathic sandstone is a feature worthy of record. During the coking of the coals the loss of bituminous matter has been accompanied by a more than proportionate increase in the percentage of ash, the additional inorganic material having been introduced by infiltration into the vesicular coke of salts in solution subsequent to the consolidation of the igneous rock.

VI.—EXPLANATION OF MAP AND PLATE.

MAP.—The stratified rocks (Talchirs and Barakars) are confined to a basin-shaped depression of about 11 square miles with two inliers of crystalline rocks (shaded in pink) in the north-west corner. Outside the boundary of the sedimentary rocks, which are sometimes cut off by a fault and sometimes limited by a natural boundary, the country consists of various crystalline rocks, felspathic gneiss and mica-schists being specially common. Quartz veins and veins of coarse graphic granite frequently occur in these. The direction of foliation of the crystalline rocks varies within small limits, but generally conforms to the direction of the main faults which bound the coal-field on its northern and southern margins, besides dividing it in a parallel direction near the centre. The northern boundary fault coincides for some distance with a dyke of eurite, the face of which probably affords a plane of low resistance. The position of the diorites has been marked at Chepo Hill and Gujiadih on the south, at Bonkhoonju on the north, and at Paharidih, Birwadih and Mongrodih on the east. Wherever these rocks are foliated, the foliation is parallel to the general foliation of the crystalline series around, and, consequently, to the direction of the great faults of the field. The diorite forming the conical mass at Bonkhoonju is not foliated, but the gneisses dip on both sides towards the hill, forming a syncline whose axis runs about east-north-east and west-south-west (*vide* paragraphs 10—21). Catalogues of the peridotite and basalt dykes are given in the text (paragraphs 33 and 37). Their position and names are plainly indicated on the map. The positions of property boundaries (indicated by thin lines joining the pillars) are shown for the purpose of finding in the field any required outcrop, as some of the dykes are so small and decomposed that they are not often easily detected.

PLATE.—*A series of photographs of thin sections under the microscope.*

FIG. 1. *Pyroxene-plagioclase rock* from Mongrodih near Giridih. Magnified × 20 diameters. The white felspars in long flat crystals are surrounded, with an imperfect ophitic arrangement, by augite. Some of the pyroxene, probably rhombic in some cases, has formed very fine mesh-work fringes on changing to hornblende and by reaction with the adjoining felspars, which latter have consequently lost their sharp outlines. Opaque iron-ores often occur in the patches of granular hornblende and sometimes form the nucleus of a garnet

aggregate. The change to green hornblende has taken place along the margins of nearly all the pyroxenes, as shown by the large crystal on the left.

FIG. 2. *Epidiorite with scapolite.* Mongrodih, near Giridih. Magnified × 20 diameters. The rock consists of a granular aggregate of hornblende scapolite, felspar and quartz. The scapolite may be recognised amongst the colourless constituents by the slight streakiness produced by incipient decomposition. This rock occurs near the margins of the mass of which fig. 1 represents the centre. The rock represented by fig. 1 consists of pyroxene and plagioclase, the latter constituent containing a series of cavities infilled with sodic chloride solution. As the result of subsequent dynamical metamorphism, the ophitic intergrowths shown in fig. 1 have been destroyed, the augites changed into granular hornblende, and the mixture of plagioclase and sodic chloride converted into scapolite with a small residue of clear felspar and quartz.

FIGS. 3 & 4. Crystals of *plagioclase-felspar* from the pyroxene-plagioclase rock of Mongrodih. Magnified × 37 diameters. Fig. 3 under ordinary light shows the bands of secondary inclusions of sodic chloride, which, when viewed between crossed nicols (fig. 4), are seen to coincide with the planes of composition of the lamellar twins. The statical metamorphism has thus resulted in the solution of the felspars along the planes of composition, which are regarded by Professor Judd as planes of chemical instability. The felspars in this rock afford very striking illustrations of the production of this form of schillerization along the planes between the twin-lamellæ (*cf.* Judd *Min. Mag.*, Vol. VIII (1889), pp. 189, 197).

FIG. 5. *Epidiorite* approaching *hornblende-schist*, Gujiadih, south of the Giridih coal-field. Magnified × 20 diameters. This is one of the extreme results of the metamorphism of the pyroxene-diorites, which, near the southern margin of the coal-field, are changed into well foliated hornblendic and granulitic rocks *without* the development of the scapolite that so frequently characterises the corresponding types on the north and east.

FIG. 6. *Felspathic sandstone*, partially fused by an intrusion of peridotite. Bhaddoah hill, magnified × 20 diameters. The quartz crystals have been corroded into bays and channels by the fused hydrated silicates, and the cooling of the latter has given rise to radial arrangement of black microlites precisely similar to those in the imperfectly crystallized matrix of many rhyolites.

R.D. Oldham. Records, Vol: XXVIII. Pt. 4. Pl. 5.

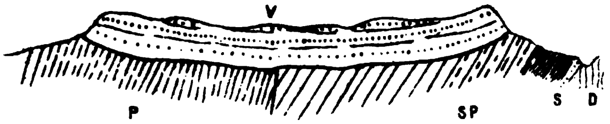

FIG. 1. SECTION THROUGH EAST END OF THE KHARARA OUTLIER.

Sb, Basal Beds. V, Vindhyan. SP, Porcellanites of the Sub-Kaimur series.

P, Beds older than Sub-Kaimur.

FIG. 2. SECTION NORTH WEST OF BARHATA.

Lettering as in fig. 1.

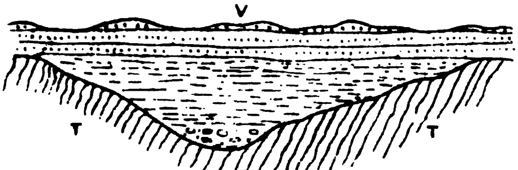

FIG. 3. SECTION AT RIGHT ANGLES TO 2

Scale of Sections 2" = 1 Mile.

Reg No 473, Dir., Geol. Surveys — Sept 95. — 660. Imp. S. I. O., Calcutta.

On some outliers *of the* Vindhyan system South *of the* Son and their relation *to the* so called lower *Vindhyans: by* R. D. OLDHAM, A.R.S.M., F.G.S., *Superintendent, Geological Survey of India* (with plate 5).

It has long been known that the Vindhyan system proper is underlaid, in Bundelkhand as in the Son valley, by a series of shales and limestones, regarded as conformable to the overlying system of sandstones, though their true relationship had not been fully cleared up. This series of shales and limestone was consequently accepted as a member of the Vindhyan system under the designation of lower Vindhyan.

The earliest published reference to these rocks is in a communication by the late Dr. T. Oldham to the Asiatic Society in 1856. In this the term Vindhyan was first proposed[1] for the system of sandstones and associated shales and limestones to which it is still applied. The beds below the Kaimur sandstone, which were subsequently accepted as lower Vindhyan, are there separated from the Vindhyans, under the name of 'Sub-Kymore,' a term proposed by Mr. H. B. Medlicott[2] to cover all the rocks below the Kaimur sandstone.

The next reference to these rocks is in Mr. Medlicott's memoir on Bundelkhand, where a very similar series of rocks is exposed in a corresponding position. The name 'Sub-Kymore' is abandoned and the series in question named Semri.[3] Reasons are given at one place[4] for considering the Semri beds as conformable with the Kaimur sandstone, but in other passages irregularities in the distribution of the upper groups of the Semri series are described, which do not seem compatible with complete conformity. Apart from this, the Kaimur conglomerate is said to contain pebbles of the chert-like shale of the lower Semri groups.[5] The observations recorded indicate a relation between the Kaimur sandstone and the underlying beds very similar to that which is found in the Son valley.

In the same volume the beds below the Kaimur sandstone in the Son valley are referred to by Mr. J. G. Medlicott under the name of Sub-Kymore;[6] no details are given, and, as in the original publication,[7] the term was evidently used to include rocks that are now separated as transition besides those which have come to be called lower Vindhyan.

This term was first publicly used in 1869 by Mr. F. R. Mallet in his account of the Vindhyan system[8], or series as it was then called; and in introducing the name it is said that recent investigations had established the identity of the Semri series of Bundelkhand and the Sub-Kaimur series of the Son valley, "at the same time establishing their close connection with the formation hitherto known as the Vindhyan. This connection, although close, is not sufficiently so to warrant our including both in one series. Hence the latter are now called *Upper Vindhyan*, the Semris and

[1] *Jour. As. Soc. Beng.*, XXV, 251 (1856).
[2] *Ibid*, p. 253.
[3] *Mem. Geol. Surv. Ind.*, II, p 6 (1860).
[4] *Ibid*, p. 13.
[5] *Ibid*, p. 28.
[6] *Mem. Geol. Surv. Ind.*, II, 138 (1860).
[7] *Jour. As. Soc. Beng.*, XXV, 253 (1856).
[8] *Mem. Geol. Surv. Ind.*, VII, 27 (1869).

Sub-Kymores being distinguished as *Lower Vindhyan*."[9] In the descriptive portion of the memoir a closer connection is described than these words would suggest, facts and arguments being detailed which would indicate a complete conformity between the two series.[10] These are, firstly, the parallelism of dip observed along the boundary of the two series; and secondly, the absence of any signs of erosion on a contact section seen in the Dargaoti valley. At the same time other observations are recorded which are hardly compatible with complete conformity, but as it will be necessary to recur to this subject further on, its consideration will be deferred for the present.

In the first edition of the Manual of the Geology of India Mr. Medlicott's description of the Vindhyan series follows that of Mr. Mallet so far as the Son valley is concerned, and it is definitely stated[11] that the upper Vindhyans in this area conformably overlie the lower. This is to a slight degree qualified in another passage,[12] but the general impression left by the description is that there is no break of any importance between the two, and that the lower Vindhyans, so called, form part of the same great system of deposits as the upper.

When preparing the second edition of the Manual, I was struck by the indications of an unconformity, which are to be found in the original descriptions, and though the description of a region and system with which I had no personal acquaintance was left unchanged, except for some condensation, I felt it necessary to lay more stress on the possibility of an unconformable break between the two series and to question[13] the propriety of classing them together under one system.

Such was the state of our knowledge of these rocks till, during the last working season, upper Vindhyan outliers were found south of the Son, which have an important bearing on the relation of the so called lower Vindhyans with the Vindhyans proper. The subject is far from worked out and the region is still under survey, but some of the facts are clearly enough established to be worth publishing, in view of the interest attaching to this system.

The existence of Vindhyan outliers in the Son valley south of the boundary of the main area has long been known, and several are indicated on the map accompanying Mr. Mallet's memoir, but they had always been regarded as belonging to the so called lower Vindhyans.[14] During the past season several of these have been more or less completely examined, and it was found that they are of two distinct types and belong to two distinct series. We have firstly patches of unmistakable 'lower Vindhyan' rocks, highly disturbed and folded or faulted among the older transitions, and secondly outliers of much less disturbed and often nearly horizontal sandstones and conglomerates, which in one place were found to rest unconformably on the beds of the 'lower Vindhyans.' From their degree of induration these sandstones must be separated from the Gondwanas and, being younger than the 'lower Vindhyans,' may be referred to some horizon of the true or upper Vindhyans, which they resemble in lithological character and degree of induration.

[9] *Mem. Geol. Surv. Ind.*, VII, 27 (1869).
[10] *Ibid*, p. 46 ff.
[11] *Manual of the Geology of India*, 1st ed., 1879, I, p. 81.
[12] *Ibid*, p 90.
[13] *Manual*, 2nd ed., p. 98.
[14] *Mem. Geol. Surv. of Ind.*, VII, 45, *Manual*, 1st ed., p. 75.

We have accordingly south of the Son representatives of two series which to the north are apparently conformable, and as it will be inconvenient to call these by the same name, I propose, for the present, to resume the name of Sub-Kaimur for the 'lower Vindhyans.'

The only outlier which has been completely surveyed is that which lies west of the Samdin and south and east of the Son. Its position is indicated in the map accompanying Mr. Mallet's memoir, and it is at once the most westerly and the largest of those which must be ascribed to the newer series of rocks, or upper Vindhyans. Along its south-eastern margin a few small outlying patches of the same series are found, but to the north none exist between it and the Gidela outlier of the Kaimur scarp.

The outlier referred to is 12 miles long from east-north-east to west-south-west, of irregular shape, varying from half a mile to three miles in width, about the middle of which rises the Kharára G. T. S. Round the whole length of its boundary, except for a couple of miles where this is faulted, the outlier rests in obvious unconformity on the older underlying rocks. The rocks of which it is composed consist essentially of hard sandstones, white or red, many of which resemble the sandstones of the upper Vindhyans, more especially of the Kaimur group, though the series as a whole differs in the large number of pebbles it contains and in the frequent presence of a considerable proportion of felspathic material, whether as distinct grains of felspar or as a fine-grained felspathic paste. The pebbles are mostly of white vein quartz, generally small and ill rounded or angular, scattered through the sandstone matrix ; at times however and in certain beds, which are not always at the bottom of the series, larger and better rounded pebbles are found in such abundance as to constitute a conglomerate. When this is the case a considerable proportion are found to consist of a bright red jasper, and the rock then resembles the descriptions of the Kaimur conglomerate.

Reserving more detailed description till a general account of the unsurveyed area in Rewah can be given, there are two sections which may be referred to here. The first of these is in the Samdin valley below Sejári village. Just below this village the Samdin flows over a barrier of vertically dipping quartzites of the Bijáwar type, the layers being separated by papery films of micaceous iron ore. Immediately north of this there is a thin layer of breccia, followed by conglomeratic sandstone, hardly visible in the stream bed, but easily seen a short way off on either side, followed by shales, by the porcellanic beds of the Sub-Kaimur series and by sandstones above these, the ascending section being cut off by a fault with an upthrow to the north. These Sub-Kaimur beds are at the western extremity of a long narrow outlier which has been traced, with a width dwindling from a mile and a quarter to nothing, for a distance of 25 miles to east-north-eastwards ; the southern boundary being throughout natural and the northern faulted.

West of the Samdin the Sub-Kaimurs form the slope of a hill, capped by the eastern scarp of the Kharára outlier, the relations of the two series being indicated in the section No. 1 on the accompanying plate. This section is an absolutely decisive one, establishing beyond possibility of doubt that the sandstones and conglomerates of the outlier are distinct from those of the basal group of the Sub-Kairmur series to which they have been referred in previous publications.[15] The

[15] Memoirs, VII. 33.

observations of these outliers on which all previous accounts are based appear to have been made by Mr. Medlicott during a rapid march up the Son valley, the only record of which is contained in a manuscript report. Speaking of this Kharára outlier he says: 'On a first examination of this region from the north side, as actually occurred to me, one is disposed to look upon the rock of the high ridge as an overlapping remnant of an *upper* band of sandstone. For some time I entertained the conjecture that it might even be an upper Vindhyan rock.' This conjecture was abandoned for reasons which it is needless to detail here, and the sandstones of the outlier were ultimately accepted as identical with those of the basal group of the Sub-Kaimur series to the north, which, it must be acknowledged, they very closely resemble. Had Mr. Medlicott crossed the section in the Samdin, there can be no doubt that he would have adhered to his original conjecture, for here it is impossible to regard the two as identical. The Sub-Kaimur basal conglomerate and sandstone in the Samdin valley near Sejári is very much thinner than the same rock at the boundary of the main exposure, not five miles off; the thickness varies very much, but nowhere exceeds 100 feet, and the rock itself is a dirty sandstone containing small and scattered pebbles. The outcrop cannot be traced up the talus slope into actual contact with the outlier on the hill slope: it seems in fact to be cut off by a fault, but it is found within less than a quarter of a mile of the hard, clean, white, sandstones of the hill top, at whose base is a conglomerate containing numerous rounded boulders of quartz and scarlet jasper as large as a man's head, cemented by a clean silicious matrix. Even if these rocks did not rest unconformably on Sub-Kaimur beds, the great contrast in thickness and character of the two sandstones and conglomerates would leave no room for doubting their distinctness.

The other section to be considered is near the western end of the outlier and is interesting as showing the conditions under which the rocks composing the outlier were deposited. North-west of Barhata village the sandstones do not rest directly upon the older rocks, but are underlaid by a breccia composed of angular fragments of the underlying slates, a few inches in diameter, through which are scattered blocks of vein quartz running to as much as a foot in diameter. Towards its base this rock is almost devoid of fine grained matrix, but it passes by a gradual increase of sand and decrease of slate fragments into the overlying sandstone. The breccia, which is evidently an indurated fan deposit, attains a maximum thickness of over 700 feet, and is underlaid by a coarse conglomerate containing many ill-rounded pebbles of jasper, and numerous white quartz pebbles of six inches and more in diameter, besides darker and less conspicuous pebbles of quartzite, the whole being cemented by a matrix of dark red sandstone.

The section just described is figured in No. 2 of the plate, but these rocks below the sandstone do not continue along the outcrop to the east or to the west. The conglomerate is the first to disappear, its whole extent being less than quarter of a mile. The breccia extends further, but it too gradually thins out and disappears at three-quarters of a mile to the eastwards and half a mile to the west, as is indicated on the section No. 3, drawn at right angles to No. 2.

The explanation of these sections is evidently that the sandstones were deposited on a deeply eroded surface. At the bottom of the valley we have a coarse conglomerate deposited by a rapid torrent; this is succeeded by a fan deposit which

gradually filled up the whole valley, and was itself covered up by the sandy deposits which obscured all the pre-existing irregularities of the surface, and converted what was once hill and valley into a broad sandy plain.

A similar lesson is taught by the Dádri outlier, about fifty miles east by north from the eastern extremity of that just described. West of it there runs in an east by north direction a ridge of vertical Bijáwar quartzites, which owes its prominence to the comparative softness of the rocks on either side. Just west of the boundary of the sandstone outlier this is breached by a cross valley, but is continued on the plateau as a low ridge, rising out of the sandstones on either side, which runs for a couple of miles before being finally covered up. Here it is evident that the older rocks had undergone practically all the disturbance they now exhibit before the still nearly horizontal sandstones had been deposited, and had, besides, been exposed to sub-aerial denudation for a period long enough to produce an uneven surface in which the harder beds were represented by elevations and the softer by depressions of the surface.

These remarks regarding the relation of the outliers to the older rocks apply to the Sub-Kaimurs almost as much as to the transition rocks, for the amount of disturbance they have undergone in their outliers is great, and they had shared in the same denudation to which the transition rocks were exposed. It would consequently be difficult to find a more decided unconformity than that between the sandstone outliers on the hill tops, and the Sub-Kaimur series in their proximity, and a question arises as to the age of the former. To this only one answer seems possible: they are certainly of later date than the Sub-Kaimur series, and it would be preposterous to suppose that these indurated and ancient looking sandstones could be the same as the soft sandstones of the Gondwana series. It would be almost equally absurd to suppose they form a separate series of deposits by themselves not referable to any other in the neighbourhood, and the only alternative is to regard them as outliers of the upper Vindhyans, for which they might easily pass. They cannot be identified with any specific horizon of that series, and though they resemble the Kaimur groups more than any of the upper sandstones, no importance need be attached to this, as the points of resemblance are probably the result of their being in either case the bottom beds of the series.

Accepting this identification, it would be natural to suppose that the facts given above would settle definitely the distinctness of the so called 'lower' from the 'upper' Vindhyans or Vindhyans proper. Such a conclusion must not however be too hastily adopted. In the second edition of the Manual of the Geology of India I have pointed out that the nature of the north-west boundary of the Vindhyans towards the Aravalli mountains presents some analogy with that of the tertiary and recent deposits of the Gangetic valley to the Himalayas, and suggested that the Vindhyans may have been formed during the compression and elevation of that range from its debris.[16] Now along the edge of the Himalayas we have instances of upper members of the tertiary series resting in unconformable contact on the upturned and denuded edges of the lower ones, while not far off may be found a continuous conformable section uniting the two. Similarly, it might be supposed that in the Son valley we had the upper members of the Vindhyan system overlapping on to the eroded edges of the lower beds, which had been involved in the mountain forming

[16] *Manual*, 2nd ed., p. 103.

processes going on along the margin of the basin of deposition, and this unconformity at the margin need not be incompatible with a complete conformity of the two further away from that margin.

There is, however, one flaw in the analogy, which appears to be a serious one. Along the southern margin of the Himalayas the general dip is northwards, and the outliers of the tertiary beds have for the most part a natural boundary to the south and a faulted boundary to the north, the upthrow being on the north, or mountain, side of the fault. In the Sub-Kaimur outliers the conditions are reversed, the natural boundary is to the south, the faulted are to the north, that is to say, both dip and upthrow are away from what should have been the mountain range and towards the basin of deposition. These facts point to the period of disturbance as having been altogether anterior to, and not contemporaneous with, the deposition of the upper Vindhyans; and if we add to this the indications that are to be found in the published description, and still more so in manuscript reports, of both overlap and transgression along the southern boundary of the main area of the Vindhyans, it is at any rate conceivable that there is a real unconformity there, in spite of the apparent conformity, on individual sections, which has been recorded.

The final settlement of this question must await a re-examination of the boundary of the Vindhyans proper, at present the case for the inclusion of the Sub-Kaimur series with them has been greatly weakened, and until we have more positive evidence of conformity along the main boundary of the two, it will be well to abandon the question begging name of 'lower Vindhyan' for the Sub-Kaimur series.

Notes on a portion *of the* Lower Vindhyan area *of the* Sone Valley, *by* P. N. DATTA, B. SC., F. G. S., *Geological Survey of India.*

Area defined.

The area, on the examination of which these notes are based, is that portion of the Rewah State in Central India which extends on the one hand from the Kaimur Range on the north to the Sone river on the south, and on the other from the stream by Hinaota, 12½ miles W. by S. of Ramnagar on the west to the neighbourhood of Churhat on the east.

The Lower Vindhyans of the Sone Valley as classified by Mr. Mallet.

The rocks of the Sone Valley designated 'Sub-Kaimur' by Mr. Medlicott and regarded as the equivalent of his 'Semri' system of the Bundelkhand area, have been described by Mr. F. R. Mallet as the Lower Vindhyans. In his memoir on these Lower Vindhyan rocks of the Sone Valley, Mr. Mallet arranges and classifies them into the following 'sub-divisions'[1]:—

(Descending order.)

11. Limestone.
10. Shales.
9. Limestone.
8. Shales, sandstone.
7. Limestone.

6. Shaly sandstone.
5. Porcellanic shales.
4. Trappoid beds.
3. Porcellanic shales.
2. Limestone.
1. Conglomerate and calcareous sandstone.

The classification of the Lower Vindhyans, as now proposed.

From the inconstancy of some members of the Lower Vindhyan rocks and the absence of such well-defined divisions as are noticeable in the Upper Vindhyans, the Lower Vindhyans have not been regarded as susceptible of arrangement into well-marked divisions like the Upper Vindhyans. From the detailed examination of the portion of the Lower Vindhyan ground under notice, however, it seems quite feasible to classify the rocks into the following well-marked divisions :—

(In descending order).

IV. Rhotas division.
III. Kheinjua division.
II. Porcellanic division.
I. Conglomeratic division.

Origin of the divisional names.

The term 'Rhotas' has been suggested from the ancient fort of Rhotasgurh[1], while 'Kheinjua'[2] has been proposed from the Kheinjua Hills which show these rocks. I propose the name 'Porcellanic' for the next underlying division of beds from the prevailing and well-marked porcellanic character of the rocks. From the absence, in this limited area, of a particular locality or land-mark where the beds which underlie the porcellanic division and form the base of the system, are well shown, I am at a difficulty to suggest at present a more suitable name than that of 'Conglomeratic' for these beds forming the bottom division of the system. We might name the division from the well-marked range which occurs between Saria and Bela, marking the edge of the basin and exhibiting well the bottom conglomerate and quartzite. But unfortunately the range is not named in the map at all. Hence the term 'Conglomeratic' has been chosen provisionally.

Thus we have the Lower Vindhyans classified into the following four divisions :—

IV. Rhotas	division,	including	Nos. 11, 10 and 9[3]	of	Mr. Mallet's	'sub-divisions.'
III. Kheinjua	,,	,,	,, 8, 7 and 6[4]	,,	,,	,,
II. Porcellanic	,,	,,	,, 5, 4 and 3[5]	,,	,,	,,
I. Conglomeratic		,,	,, 2 and 1[6]	,,	,,	,,

Distinctive characters of the several divisions.

Distinctive characters of the different divisions.—While the Rhotas division is mostly calcareous—it is entirely so in the area under notice,—and the Kheinjuas are essentially argillaceous shales with sandstones, the peculiar feature of the beds

[1] Mem. G. S. I., Vol. VII, p. 28.
Manual, 1st Ed., Pt. I, p. 78.
,, 2nd Ed., p. 95.
[2] This term appears to have been first adopted on the field maps of Mr. W. L. Willson, late of the Geological Survey.
[3] Mem. G. S. I. VII, pp. 28, 42, 43.
[4] ,, ,, ,, pp. 28, 38—41.
[5] ,, ,, ,, pp. 28, 35—38.
[6] ,, ,, ,, pp. 28, 31—35.

composing the Porcellanic division is indicated by the name itself. The bottom division is mainly arenaceous, the calcareous and argillaceous element being present only to a very subordinate extent.

IV.—RHOTAS DIVISION.

In the area under notice the shales No. 10 of Mallet's are nowhere developed. Thus the division bed consists entirely of thin-bedded limestone. The bottom beds of the division exhibit a tendency towards concretionary character, well formed calcareous concretions being often developed.

Rhotas division.

Crystals of quartz have been found developed in the drusy cavities in the limestone in some places.

Much local puckering and crumpling is observable in these thin-bedded limestone beds, but the topmost beds—those by the junction with the Kaimur beds—show no evidence of disturbance.

III.—KHEINJUA DIVISION.

The sub-divisions 8, 7 and 6 make up this division. But in the area under consideration it is divisible into the following well-marked series:—

Kheinjua division. Sub-divided into 8 series.

(In descending order.)

i. *Argillaceous shales*, containing calcareous concretions with intercalated limestone beds. Arenaceous element almost absent.

ii. *Limestone band*—
Limestone pure; no arenaceous or argillaceous element present.

iii. *Shales*—Arenaceous and argillaceous, with thin-bedded sandstone; ripple-marked; no calcareous beds.

iv. *Limestone with shales*—
Limestone very impure and ripple-marked; shales reddish, sometimes calcareous, at other times not.

v. *Shales*—
Arenaceous and argillaceous; much ripple-marked, and with quartzitic thin bands of sandstone.

vi. *Sandstone*—
Thick-bedded, compact and quartzitic.

vii. *Limestone with shales*—
Limestone purer than No. iv; shales greenish and non-calcareous.

viii. *Shales and sandstones*—
Sandstone generally thin-bedded; shales greenish and laminated.

Of these series (i to viii) the limestone No. ii has been traced as far as Rampur, where it dies out. The series No. iv persists throughout the area, while the limestone vii is not traceable beyond "Ucheyra" of map, near Marjátpur; but a limestone appears again about this horizon at 2 miles S. E. by S. of Rampur (Lat. 24°19′ N., Long 81° 32′.5 E.) and continues eastwards, becoming concealed under the alluvium at the eastern extremity of the area.

Persistence or otherwise of the several calcareous series in the division.

II.—PORCELLANIC DIVISION.

This division is divisible into—

Divided into three sub-divisions.

Upper Porcellanic shales,	corresponding to	No. 5 of Mallet.
Trappoid beds	"	" 4 " "
Lower Porcellanic shales	"	" 3 " "

Looked at broadly, the bulk of the division is composed of the fine-grained porcellanic shales, and in their midst, and rather nearer the base than the top, we find a band of coarser rocks to which the name "Trappoid" has been applied. The upper porcellanic shales have a considerable quantity of ordinary argillaceous shales, very little altered, intercalated in them. The "trappoids" are thoroughly well bedded, in beds often of the same thickness as the porcellanic shales They do not form a well definable band by themselves, but occur intercalated with the finer-grained porcellanics. The trappoids are generally of a bluish color, but vary in fineness of grain, some being like exceedingly fine-grained quartzites, while others are much more coarse and gritty, with the quartz grains generally rounded. Felspar is present, but is scarcer in certain parts than in others. No hornblende could, however, be detected in the area under notice.

I.—CONGLOMERATIC DIVISION.

COMPRISES { No. 2. Limestone.
No. 1. Conglomeratic and calcareous sandstone.

Farther subdivision yet impracticable from want of good exposures in this area.

As no exposures were available in the area in question for a minute examination of the constituents of Mr. Mallet's 'subdivision' No. 1, *viz.*, the conglomeratic and calcareous sandstone, the 'subdivision' has been allowed for the present to stand as it was. The limestone, coming in just above the conglomeratic and calcareous sandstone, does not seem very prominent or remarkable in any way, but on the other hand seems to be of a very inconstant and variable character. So it seems preferable to take in the Limestone No. 2 with the 'Conglomeratic and calcareous sandstone' beds, and form the two into one division. It seems all the more reasonable to do so, as we find it stated that the lowest two 'subdivisions' (*viz.*, No. 2 Limestone and No. 1 conglomeratic and calcareous sandstone) appear to be in some measure equivalent to each other[7], a conclusion presumably based on an examination of the rocks over the whole area.

General composition of the conglomeratic division.

Although for want of suitable exposures in this area a proper subdivision of the division has not yet been possible, the following is the general composition of the division. The limestone (limestone "No. 2") passes into a dark bluish earthy rock, ferruginous in places; shale, sandstone with quartz and ferruginous bands and quartzitic sandstone, light to dark grey and fine-grained to coarsish, are next seen, while lower down, ferruginous calcareous beds with pale greenish shale passing down into a greenish argillaceous shaly sandstone come in close above the quartzite which forms the range between Bela and Saria. This quartzite, which is thick-bedded, compact and hard, and reddish to white in colour, has hardly any pebbles in its upper part, but becomes conglomeratic in the lower part, the pebbles being of white and reddish quartz, red jasper and quartzite.

Conformability of the several divisions of the Lower Vindhyans and relation to Upper Vindhyans.

All these divisions, IV to I, which make up the Lower Vindhyans, are conformable to one another. As to the relations of the Lower Vindhyans (1) to the rocks that underlie the system and (2) those that overlie the system :—

[7] Manual, 2nd ed., p. 95.

(1) The lower junction of the bottom conglomerate (division I) of the Lower Vindhyans (or Semri) rests unconformably upon a gneiss in the area under examination.

(2) The upper junction of the Lower Vindhyans (that is, the Kaimur-Rhotas junction) has been stated to be unconformable on these grounds:—

  (*a*) That the Kaimur beds overlap the Lower Vindhyans.

  (*b*) The occurrence of Lower Vindhyan debris in the Kaimur beds 100 ft. or more from the base of the Upper Vindhyans [8]

  (*c*) The existence of a sharp line of division between the Kaimur and the Rhotas, especially in the sudden and abrupt change from the fine-grained deposits of the Rhotas to the coarse sandstone of the Kaimur.[9]

Overlap does not necessarily prove unconformity.

With reference to the unconformity from overlap, it is apparent that overlap need not always imply unconformity. The existence of overlap would not by itself prove any unconformability if unsupported by other evidence.

Denudation unconformity.

As to erosion-unconformity. The occurrence of Lower Vindhyan debris 100 ft. or more above the base of the Kaimurs has found neither confirmation nor negation from my personal observations in this area. For, though in the course of my examination, I cannot say I could detect any such Lower Vindhyan debris in the Kaimur beds, it must be remembered that the slopes of the Kaimur scarp in the area in question are exceedingly unfavourable for close examination. The Kaimur conglomerate is absent in this area.

No Kaimur-Rhotas contact proving erosion could be detected here.

Whenever the state of exposure allowed an examination of the ground to be made, I never succeeded in coming upon a contact of the Rhotas limestone with the rocks above indicating erosion-unconformity. The shales[10] overlying the Rhotas limestone certainly seemed thicker in some places than in others, but whether this was due to the original variability in the thickness of the shaly deposit, or to denudation of the underlying limestone rock in places (where the accumulation of shales would thus be greater than elsewhere) before the deposition of the shales, or to local depression in the rim of the basin which would thus take out of sight some of the lower beds, it was difficult to make sure. Should there have been denudation in the case, the contact between the limestone below and the shales above ought to show evidence of erosion somewhere or other. But although I did not succeed in coming upon an exposure proving the denudation of the limestone before the deposition of the shales, this does not of course disprove its existence, having regard to the nature of the ground.

Disturbance of Rhotas limestone not anterior to deposition of the Kaimurs.

There is certainly much evidence of disturbance in the beds of the Rhotas limestone, often in close vicinity to the base of the Kaimurs which are, however, quite undisturbed. That the Rhotas limestone might have been disturbed and contorted before the deposition of the Kaimurs is contradicted by

[8] Mem. G. S. I, VII, pp. 47 and 50; Manual, 2nd ed., p. 99.

[9] Mem. G. S. I., VII, p. 47; Manual, 2nd ed., p. 99.

[10] These are the Bijaigarh shales in all probability.

the invariable complete parallelism of the topmost Rhotas limestone with the Kaimurs, which has been observed in this area wherever a clear point of junction has permitted an examination.

As to unconformity from abrupt change in lithological character.

With regard to the unconformity as inferable from sudden change in lithological character from the Rhotas into the Kaimur beds, the examination of this junction in the area under report has been found to be attended with circumstances of considerable disadvantage, for the débris from the steeper parts of the Kaimur scarp form in most places a talus along the lower slopes of the scarp, rendering it a most difficult task to come upon an exposure showing a clear point of junction of the Rhotas limestone with the Kaimur rocks. The following are some of the localities where the sections at or near the junction were found to be instructive.

Section at Gursari ghat.

Gursari ghat.—Here the siliceous shales [11] (the shales that overlie the Rhotas) are seen to pass normally into the Kaimur sandstone of the scarp. The junction of the shales with the Rhotas is, however, concealed here.

Section by Hinaota.

Scarp-slopes by Hinaota.—(Approximate position, Long. 81°19'E, Lat. 24°18'N.). The exposure here too is not perfect, but the Rhotas limestone seems to pass into a fine-grained homogeneous shale which, when freshly broken or exposed, is green, but turns bluish chalky white on exposure to the air. Such a rock is what we should expect to meet with as a passage rock from a limestone. For a little space up the slopes, above the foregoing shale, the ground is covered, but the shales that are exposed a little higher up are somewhat siliceous, and these pass above into the thick-bedded sandstone of the Kaimur scarp.

Exposure by Daorahra.

Foot of scarp-slopes, N. W. Daorahra.—Near Boorgaona. The homogeneous shale referred to as being met with in the last mentioned locality is also exposed here. But neither the junction of the Rhotas limestone with this shale, nor the passage of this rock into the siliceous shales and sandstone above, is traceable here.

Section by Majgama.

Scarp-slopes N. W. of Majgama.—The foot of the spurs is occupied by the Rhotas limestone. A little way up (*i.e.*, after a short blank section) a finely laminated soft shale, white, grey to blackish is seen (the shale is occasionally blackish enough to look carbonaceous). These soft shales pass upwards into shales somewhat harder, the colour being yellowish to brownish-grey, with a faint approach to a porcellanic look.[12] Beyond this point a talus of sandstone obscures the section, but the thick-bedded sandstone of the scarp is close above.

Section at Reiwas Hill.

Reiwas Hill.—(4½ miles N. by E. of Rampur, Lat. 24°24'·5 N, Long. 81°33' E.) At the S. E. extremity of this hill, although the exact point of junction (Kaimur-Rhotas) is not to be seen, the uppermost Rhotas limestone as well as the shales above are well exposed. Just above the uppermost limestone, a few feet of blank section covered over with shale débris, intervenes, beyond which occurs a laminated shale, somewhat blackish

[11] The shales coming in immediately above the Rhotas limestone in this area are probably Bijagarh shales, as already indicated.

[12] One is here reminded of the circumstance that south of Saranga, near Mirgaoti, we find a limestone passing down through a white earthy rock into a porcellanic shaly rock.

in colour in places, and very slightly, if at all, siliceous. This shale is succeeded by some more shales which are earthy and somewhat porcellanic. Over these comes in the thick-bedded sandstone. The dip of the limestone as well as of the shales above is N. 15° W. at 11°.)

The above sections show conformity, and indicate gradual passage.

In all these instances not only is a perfect conformity observable between the Rhotas limestone and the Kaimur beds, but also a gradual passage indicated from the one into the other.

Conclusions with regard to upper boundary of the Lower Vindhyans.

Thus so far as the materials at hand will enable one to judge, this is what we can conclude with regard to the Kaimur-Rhotas junction in the area under notice—

1. That no dip unconformity is observable along this junction, but on the contrary:—
2. Wherever the section is fairly clear, there exists a complete dip conformity between the Rhotas limestone and the Kaimur rocks.
3. That no physical break in the form of abrupt change in the lithological character of the rocks is to be observed, but, on the other hand, from the few cases where the sections have been found to be tolerably clear, the indications all point in the other direction, namely, that there is a physical continuity in the passage from the Rhotas into the Kaimur beds above.

Lower Kaimur sandstone absent in this area.

In conclusion, it may be observed that if the shales which come in immediately above the Rhotas limestone are the Bijaigarh shales, then the Lower Kaimur sandstone, as well as the Kaimur conglomerate, is absent in this area. How far, however, the absence of the Lower Kaimur sandstone may be accounted for by the supposition that the lower part of the Bijaigarh shales may represent here the Lower Kaimur sandstone, that is, how far the case may here be one of only normal lateral replacement is a matter that can only be decided after more extended observation. The conglomerate, however, though it is absent here, certainly indicates a physical break. The occurrence of the conglomerate, however, above the Bijaigarh shales carries the break to the base of the Upper Kaimur beds, that is, some way up from the Rhotas-Kaimur junction. So the conglomerate as an evidence of a break is not of much account so far as the horizon of the boundary-line as hitherto assigned between the Upper and Lower Vindhyans is concerned, being placed, as it is, some distance above it.

Its absence may be due to normal lateral displacement by Bijaigarh shales.

Upper Kaimur conglomerate proves no break at Rhotas-Kaimur junction.

Note on DR. FRITZ NOETLING'S paper *on the Tertiary system in Burma in the Records of the Geological Survey of India for 1895, Part 2:* by MR. THEOBALD, *late Superintendent, Geological Survey of India.*

Having read with much interest the above paper, there are a few remarks I should like to make, as in one case the author attributes to me, as a "logical outcome" views I never contemplated for a moment, and in another matter it seems

desirable to elicit more clearly than at present whether Dr. Noetling's correction of a previous statement of mine, really can claim to be any correction at all.

I make no objection to Dr. Noetling terming the beds previously named by me "*Fossil wood group,*" the Irrawaddi division, although I cannot agree with Dr. Noetling that the name bestowed by me was "by no means appropriate," because Fossil wood was found abundantly in certain post-tertiary beds also. The term proposed by myself emphasized and pointed to the fact that in the beds so called the Fossil wood existed *in situ,* and that they were the original depository of the Fossil wood, which in the newer beds was simply derivative and the result of the re-arrangement of the materials of the Fossil wood group proper.—(p. 76 l. c.). At page 83, Dr. Noetling takes exception to a suggestion of mine that the silica with which the fossil trunks of trees had been mineralized might have been derived from springs discharging into the water, wherein I supposed the trees to have floated prior to their entrenchment. "The logical outcome of this theory is that, wherever a single specimen of a silicified log is found *in situ,* we are bound to suppose that just underneath that very log a spring rose in order to petrify it, and having done its work, disappeared without leaving behind it any other traces of its activity." Now Dr. Noetling is fully justified in calling this absurd, but he is wholly wrong in calling it the "*logical outcome*" of anything I said, wrote or thought in the matter! The silica may or may not have been supplied by springs as I suggested, but all I had in my mind was the precisely analogous case of the flint in chalk which was clearly *nascent* or in solution in the cretaceous sea, and in its gelatinous condition gathered round and mineralized any organic substance lying fortuitously at the bottom, as I supposed the silica to have done in the water wherein the fossil trunks in the 'Fossil wood group' as I termed it, did in the waters wherein they floated—before their ultimate mineralization. At page 84, Dr. Noetling makes an important correction of a statement of mine, where he says that Mr. Theobald's "statement that the silicified wood is never bored by Xylophagus mollusca is *absolutely erroneous.*" Of course I am glad to be corrected in a mistake of this kind, but in this case I am not so sure if Dr. Noetling has corrected me! By referring to my Report (Memoirs, Vol. X, p. 66) it will be seen that the fossil wood to which I refer is that of the "*silicified trunks*" which Dr. Noetling admits are embedded in a freshwater formation (p. 86, l. c.) as instanced by the absence of marine organisms. The question hence arises, does the fossil wood of which Dr. Noetling says he has "repeatedly found large pieces riddled by the borings of these mollusca" refer to the silicified trunks, to which *my statement referred,* from the topmost division of my 'Fossil wood group,' or does it refer to logs of fossil wood from the marine beds of Dr. Noetling's Pegu group, as if so it ceases to be a correction of any statement of mine whatever? I have not myself noticed in Pegu any perforated wood whatever, but that such should occur in beds of the character of the marine beds of the Pegu division of Dr. Noetling is of the highest probability, but as matters stand it seems by no means evident that my assertion touching the silicified trunks of my 'Fossil wood group' has received any real correction from any observation of Dr. Noetling—at least within the area to which my remarks were confined—it being of course quite possible that the homologous beds of the Fossil wood group of Pegu might in Upper Burma be represented by beds of an estuarine character rather than a lacustrine or fluviatile one, in which case Dr. Noetling's observation would be perfectly correct, without implying any correction of my own.

Notes from the Geological Survey of India.

I. Madras.– Mr. Middlemiss reports having met several corundum pits in the Sivamallai district of Coimbatore, and in some of these shallow pits magnetic iron ore also appears, concentrated into lumps among the felspar, forming a rich rock with a specific gravity of 3·95. Magnetic iron ore was found as a schist and standing up as a small hill near Hallagomallai. The same rock was also found forming the Chinnamallai (Sennamallai) hill-range near Peranturei, the strike in the rocks coinciding with the long axis of the range.

Mr. Middlemiss also examined the extensive marble beds near Madukarai, which are regularly banded with the ordinary gneisses of the area, and with which they seem to be in structural connection. The deposit appears on the Coimbatore-Madukarai road near the 6th milestone from the former place; its outcrop is roughly elliptical, the major axis running NE to south-east from the point mentioned to within 1½ miles of Kurichi village. The total length of the outcrop is about 7 miles, and the breadth varies from ½ mile to 50 or 100 yards. It is thickest on the north-west and north-east sides. The marble is greyish white, dark slate grey and flesh-coloured pink, and forms a very valuable building stone, hitherto but little used locally.

II. Burma.—During the early part of this year Dr. H. Warth examined the so-called Nanyaseik ruby tract in the Mogoung district; the area selected by the Burma Government and proclaimed a gem tract is about 80 square miles, although Dr. Warth estimates the actual area over which gems are found in the alluvial deposits as about 10 square miles only. His report will be published hereafter, but the main facts are the following:—

1. He found, in parts of the district examined, sandstone without fossils, which I believe to be the tertiary sandstone with coal seams mentioned by Dr. Noetling (Records Vol. XXVI, Pt. 1, p. 28).

2. A series of acid igneous rocks, most interesting lithologically.

3. Granitic rocks which inclose beds of metamorphic (crystalline) limestone: the latter is of importance, as it is the original matrix of the gems. Dr. Warth is of opinion that this limestone is the same and contains the same minerals as the coarsely crystalline limestone found at the Mogok and Sagyin ruby mines in Burma.

Good rubies and well-coloured spinels with some saphires have been found in the alluvial deposits of the "Nanyaseik gem tract."

III. Baluchistan.—Sub-Assistant Hira Lall surveyed geologically part of the Mari and Bugti hills east of Sibi, and has furnished a report, which will eventually be incorporated in the final Report on the Geology of Baluchistán; it is of interest to note that the great flexures into which the rocks of Baluchistán have been laid are continued into these hills; the sections seen are much the same as already reported on from the country further west and north-west (Records, Vol. XXV, Pt. 1, p. 18), and most of the beds from the massive jurassic limestone to the upper Siwalik conglomerates have been recognized.

CALCUTTA;
The 1st November 1895.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

RECORDS

OF

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VOLUME XXIX.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part I.] 1896. February.

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1895.

The actual area which was geologically surveyed during the past year is much below the amount which could have been estimated for under favourable circumstances, though perhaps not below the amount of surveys in square miles, done during each of the last few years. This, however, may easily be accounted for by the fact that not only were several officers withdrawn from survey work proper and employed on so-called economic inquiries, but there were several vacancies on the staff, which could only recently be filled up.

At the beginning of the year the officers were distributed as shown in the last Annual Report on page 1 of the Records, Vol. XXVIII.

Mr. H. H. Hayden joined the Department as Assistant Superintendent on the 21st February, too late to take up field work, and he was therefore detained at head-quarters to learn the vernacular language and to assist in laboratory work.

Messrs. Vredenburg and Grimes were appointed Assistant Superintendents by the Secretary of State to fill vacancies on the staff; both jointed head-quarters on the 16th October 1895.

During the year three officers proceeded on furlough, namely, Mr. LaTouche on the 19th March, Mr. Bose on the 15th May, and Dr. Noetling on the 1st July 1895.

At the beginning of the present camping season the staff of the survey was distributed as follows:—

Mr. R. D. OLDHAM with Messrs. DATTA, VREDENBURG and GRIMES	Rewah.
Mr. MIDDLEMISS with " SMITH	Madras.

Mr. HOLLAND . .	. Head-quarters.
" HAYDEN . .	. Burma.
Mr. ANDERSON with Dr. WARTH and LALA HIRA LAL	Chota Nagpore.
LALA KISHEN SINGH .	. Baluchistán.

During the hot weather months and the rainy season most of the officers returned to Calcutta to work up their reports and maps; Mr. Middlemiss returned to Madras at the beginning of the monsoon to continue field work.

Mr. Oldham, with Mr. Holland, proceeded to Naini Tal at the close of the monsoon to report on the stability of the hill-sides of that station.

I myself proceeded on inspection when opportunities offered, and I performed the following tours :—

During March to Chota Nagpore and Central Provinces.

During June to Naini Tal at the request of the Government of the North-Western Provinces.

During July and August to the Central Provinces and Madras.

During October to Naini Tal.

Summary of work accomplished.

In the following pages I give an outline of the work performed in the field and laboratory.

Bengal.
Mr. Anderson.
Dr. Warth.
Lala Hira Lal.

As already reported in my Annual Report for 1894, the mineralogical survey of Chota Nagpore has been begun by Mr. Anderson, the mining expert of this Department. During the camping season ending during April of 1895 he explored a considerable area of Chota Nagpore. He made traverses in many directions, beginning with the country around Borobhum, and from thence to Dhadka, Moholia and Chaibassa. East of Borobhum, to a distance of about 12 miles, the transition rocks are much intruded by dykes and masses of a hornblendic rock, probably diorite. Associated with these intrusions are innumerable quartz-reefs, many of which were tested, but show no traces of gold. Almost all the reefs of this area have generally a north and south strike, many of them occurring as joint reefs in the dykes. In the country between the Cupergadi Ghat and Chaibassa, similar dykes associated with quartz-reefs occur, but they also show no traces of gold.

I visited Mr. Anderson during March, when his first and rapid traverses were drawing to a close. A quotation from his February report will afford an idea of the work and the geological nature of the ground gone over. "During the month of February I made an examination of the country around Chaibassa, Seraikela and Sim. At the first-mentioned place the boundary between the transitions and metamorphic series runs close past the town in a north and south direction. In the neighbourhood of this boundary the rocks, particularly those of the transition series, are seamed with quartz veins. To the north and north-west of the town the outcrops of these veins are not at all well defined but usually form a series of small circular or elongated hills, composed superficially of nothing but small fragments

of quartz. In some parts these hills occur in numbers close together and cover considerable local areas. Almost anywhere in such areas the broken quartz debris, when crushed or washed, show minute traces of gold. The absence of defined outcrops would materially increase the expense and time of prospecting this area, because so much work would require to be done in trenching through the superficial debris to get at the actual reef outcrops."

During this camping season prospecting work has begun in earnest, sufficient funds having been sanctioned by the Government of India for the purchase of the requisite plant, tools, etc. A five stamp prospecting battery with all the necessary outfit has been procured, workmen are being engaged and practical investigations are being carried out in three separate mining camps. So far the traces of gold found in quartz-reefs are not encouraging, but nothing definite can be said about the prospects of finding it in payable quantities eventually, as only 70 reefs have been examined up to date.

An interesting and probably useful find of blue corundum has been made by Dr. Warth on the Balarampur-Borobhum road; it occurs in a vein of kyanite, and when opportunity offers this find will be followed up.

Rewah.
Messrs. Oldham, Datta, Vredenburg, and Grimes.

The area mapped during the field season of 1894 to 1895 was very small, little more than 700 square miles; this insufficiency may be accounted for inasmuch that both officers (Messrs. Oldham and Datta) were new to the district and were only partially acquainted with the rocks they met with during the progress of work. A considerable time was also lost by Mr. Oldham in inspecting previous work done by Messrs. Hughes, Bose and Smith in Rewah and in trying to reconcile it with his own observations and views. The result has led to some modifications of views held hitherto with regard to the so-called Vindhyan system; the chief point made out is the separation of the Lower Vindhyans (Sub-Kymores) from the Upper Vindhyans. The latter will, according to Mr. Oldham, henceforth represent the Vindhyan system proper, whilst the strata below them and above the transition rocks are to be called, as was done by Mr. Medlicott originally, the Semri series. The Vindhyans rest unconformably upon the Semri series, but it will have to be established whether in spite of the unconformability, which is only seen locally; the two series are separated from each other by a general break in deposition of the beds composing the same. Mr. Oldham has stated his views in a paper in Records, Vol. XXVIII.[1]

Besides working on the Vindhyan rocks Mr. Oldham also examined a small coal-field in the eastern part of Rewah which Mr. Smith had surveyed some years ago; the Barakar age of the rocks has now been established, as they contain *Vertebraria*, *Glossopteris*, *Schizoneura*, etc. Two coal-seams have been found, respectively of 6 feet and 5 feet 6 inches thickness; the former is 1½ miles south-west by west of Ujeini, the latter 2 miles north of Amilia, both places near the eastern edge of sheet 476.

Mr. Datta devoted the greater part of his attention to mapping the lower Vindhyans, or, as Mr. Oldham calls them once more, the Semri series. The work has been done in detail and some additions are made to our knowledge of

[1] p. 139.—On some outliers of the Vindhyan system south of the Son and their relation to the so-called lower Vindhyans.

this series. A preliminary description of the area has been given by him in a paper in the Records, Vol. XXVIII.[1]

During November Mr. Oldham took up work once more in Rewah, his staff being augmented by Messrs. Vredenburg and Grimes. So far the work of the party has not progressed far enough to add new facts to those already reviewed.

Central Provinces. Mr. P. N. Bose.

Mr. Bose continued work south-west and west of Raipur in the Central Provinces, from where he returned to head-quarters on the 6th April. He sent in a progress report from which it appears that the main features of the geological structure of that portion of the Central Provinces consists of a base of crystalline rocks, granites, and gneisses with great intrusions of felsites, on the denuded surface of which lie patches, often of large extent, of "Vindhyans"; two lithologically distinct facies of the lower division of this system have been distinguished by Mr. Bose,—the eastern or Chattisgarh facies and the western or Bhan dara rocks. The former are already known as the "Chandarpurs," whilst he proposes to call the latter the "Bagh Nadi" sandstones, a distinction which I do not consider necessary, as apparently these two facies are of the same age. There can be little or no doubt whatever that the entire sequence of beds in both areas belongs to the lower Vindhyans, as known hitherto, and my own inspection of these rocks is in conformity with this view.

Mr. Bose had taken up work in the Central Provinces as early as 1884, and has always insisted on having discovered an unconformity between the lower Vindhyans and the so-called Chilpis, a series of strata doubtfully correlated with transitions elsewhere. One of the localities specially mentioned by him was the country around Warorband, about ten miles south-east of the Dongarghar station on the Bengal-Nagpur Railway. Mr. Bose had been several times over this area, and during last field season he reported that he had obtained confirmatory evidence of his former assertion. I may here mention that Mr. Medlicott, who knew the ground, strongly differed from this view, but that Dr. King, although he thought (Records, XVIII, page 190) that the evidence was unsatisfactory, on a later occasion expressed his opinion that this unconformity had been established. The question of unconformity or otherwise remains to-day much where it was before, but during a short inspection of Mr. Bose's work during March I ascertained that the so-called Chilpi beds have no existence at Warorband itself. Believing that an inspection of that locality which he had repeatedly visited, and the survey of which he had revised as late as last season, would afford a fair test of his work, I proceeded to the place in March last, and during a few days' stay walked over the neighbouring country,—which is fairly open,—in company with Mr. Bose. I started from Dongarghar station, which I may here mention is situated on granite, which forms particularly characteristic "tors" and rugged hills in the neighbourhood, some of which are crowned with temples. The granite is seen *in situ* not only there but for miles around, and the road (ten miles) to Warorband passes almost entirely over it. There are dykes and intrusions of felsites and diorites seen in this area along with numerous and conspicuous quartz-reefs.

According to Mr. Bose we should have a sequence of older beds (Chilpis,

[1] p. 144.—Notes on a portion of the lower Vindhyan area of the Sone Valley.

consisting of grits and conglomerates, etc.) dipping at a higher angle below the Chattisgarh lower Vindhyans, the former being associated with eruptive rocks.

What I actually found was that the country about west of Warorband consists of granite, with wide belts and intrusions of felsites and diorites; these igneous rocks have long ridges of reef-quartz running nearly north and south, and on an abraded surface of these rocks rest immediately beds of the lower Vindhyans (so-called), which form the basin-like Chattisgarh series of strata, the western margin of which is slightly raised, thus dipping from 20 to 30° east and east-south-east, gradually flattening out, and even in some cases forming undulating anticlinals. The lowermost beds consist of brownish-red to purplish indurated quartz-sandstones, with strings of grits and in some places breccias and conglomerates, which strongly reminded me of the Rotas (Sone) basal conglomerate of the lower Vindhyans. The grits are not confined to beds nor to the base of the series, but as is usual in such a lithological facies, occur in strings and irregular beds at various horizons. The upper beds of this system consist of the Chattisgarh limestones, with which we have no concern here. Nowhere could be discovered any sedimentary or metamorphic rock which might have been identified with an older system than the Vindhyans, and although I am quite ready to admit that the igneous series of rocks which forms the base of the lower Vindhyans here, may be intrusive in a "transition" system, of which the Chilpis may be a local development, yet neither at Warorband nor anywhere in that neighbourhood is there any evidence of such a system, and the lower Vindhyans rest directly upon the granitic and in other places upon a felsitic or dioritic base. It seems that Mr. Bose had taken four distinct rocks as parts of the assumed "transition" series; first, the (probably) pseudomorphic quartz, which forms such numerous and most conspicuous reefs in that area and which in some places forms actually the base of the lower Vindhyans, and which being much crushed at places, has occasionally the appearance of a breccia and even grit,—that is to say, if not very closely observed; secondly, for some reason he looked upon the basal grits and conglomerates of the lower Vindhyans, where raised at a higher angle, as forming an older and unconformable series of rocks to the same beds, where the dip flattens out, or is even slightly reversed in cases of shallow synclinals, and this was the case at a point east of the Warorband lake itself; thirdly, an exposure of diorite weathering concentrically and showing that leafy condition, which in hand-specimens is often at first misleading, was mapped as intrusive in phyllites, the latter being the weathered and pseudoschistoze portion of the diorite; and lastly, Mr. Bose had identified and mapped as grits and shales of the Chilpis, a long and most conspicuous ridge made up of typical felsite. After a most careful inspection I may assert most confidently that at all events there are no "transitions" or "Chilpis" or any older sedimentary strata below the lower Vindhyans at Warorband, but that the latter rest directly upon an eroded surface of igneous rocks. That the "Chilpi Ghat series" may elsewhere underlie the lower Vindhyans unconformably is thereby not disproved of course.

The continuance of the geological survey of the Central Provinces has to be postponed owing to the fact that Mr. Bose has gone on two years' furlough.

N.-W. Provinces.
Naini Tal.
Messrs. Oldham and Holland.

After return from field work in Rewah and before the beginning of the rainy season, Mr. Oldham was deputed to Naini Tal to serve as member on the Committee appointed to report on the safety of Government House Hill. The examination was conducted during May and most of June; Mr. Oldham has sent in his report to the Government of the North-West Provinces, but the following extract from his diary for June expresses his views in outline: "The facts collected, when compared with those observed on my previous examinations leave no doubt that there is a steady downhill creep of the outer portion of the hill for a depth of probably about 50 feet. The main surfaces of separation unfortunately reach the summit under the Government House and the constant settlements which have taken place in the past, at an annually increasing rate, impressed me with the danger of a further settlement taking place, which might be sufficient to endanger the house."

As other members of the Committee dissented from this view, the Government of the North-West Provinces requested that I should give my opinion, and I proceeded to Naini Tal accordingly. Whilst I fully agree with Mr. Oldham in believing that the entire hill slope below Government House is in a more or less dangerous condition and that some day slips on a large scale may occur there, yet I did not feel convinced that distinct proofs existed of later and more extended developments of certain cracks in the hill, which had been reported on many years ago. In the absence of positive proofs that the hill-side exhibited greater signs of danger now than it did for some years past, I did not advise the Government to evacuate the hill, but to stringently enforce certain recommendations which had been made by previous committees, and also to carry out extended drainage works. One of my reasons in advising Government thus, was, that immediately after the rains a further and more detailed examination of all the hill-sides of Naini Tal was to be made by officers of the department, when the question would be finally settled. This was done during October and part of November of this year. A large scale contoured map of the station had been made by the Survey of India, and Messrs. Oldham and Holland conducted their detailed inquiries, which will be embodied in an exhaustive memoir and which ought to dispose finally of the question of the safety of this hill-station.

Madras.
Messrs. Middlemiss and F. H. Smith.

The investigations, chiefly of a petrological character, which Mr. Middlemiss pursued during 1894, were continued also during the past year, and they have added much to our knowledge of the occurrence and distribution of the magnesites and corundum o the Madras Presidency. Many of his observations are of great interest and have therefore been more fully dealt with in "notes" published in the "Records." He has sent a preliminary report, rather fully worked out, which will be published in the "Records." This cold season he is assisted by F. H. Smith, and it was hoped that the special work on which Mr. Middlemiss has now been engaged for about two years would be accelerated, but unfortunately Mr. Smith has been seriously ill with fever since his arrival in the Madras Presidency.

Sind.
Mr. LaTouche.
Lala Hira Lal.

The trial boring for oil which was commenced two years ago, progressed satisfactorily, if slow, till the 19th March of the past year, on which date Mr. LaTouche handed over the work to Lala Hira Lal, Sub-Assistant of the Geological Survey of India,

and proceeded on furlough for eighteen months. The latter was only very few days responsible for the direction of the boring, arrangements having been made to hand the same over to the North-Western Railway authorities, which was finally effected on the 25th March. Mr. LaTouche has given a short report on the boring in the May number of the Records.

The personnel of the works consisted of Mr. LaTouche with Lala Hira Lal of the Department, the latter only having joined 25th October 1894; and two American drillers, Messers. Cremer and Eady. The last named was engaged at the special representation of Mr. LaTouche, who urged the advisability of working more continuously.

When Mr. LaTouche handed over the boring to the North-Western Railway authorities it had reached a depth of about 1,100 feet, and since then it was brought down to 1,500 feet, without, however, obtaining any trace of oil. The chisel has passed through some limestone bands latterly, which may be the beds of the lower nummulitic, but to be certain, I have recommended that the boring be brought about 200 feet lower.

Salt.—While superintending the boring at Sukkur, Mr. LaTouche had occasion to examine a very interesting occurrence of rock-salt in nummulitic limestone. The spot where this mineral is found is about half a mile south-east of the village of Aror, which lies at about 4 miles east of Rohri on the left bank of the Indus.

Baluchistán and North-Western Frontier.
Mr. F. H. Smith.
Lala Hira Lal.
Lala Kishen Singh.

During February Mr. Smith examined the high range between the Lúni plain and the Zhób territory. This range is apparently formed of massive jurassic limestone, containing ammonites; its thickness is very great, and in the Wat pass, which leads through the centre of the range, it is quite 2,000 feet, all within sight, and the base is not exposed.

This grey, massive limestone is overlaid by the neocomian belemnite beds, consisting of yellowish to pink, light green and white shaly limestones and shales,—conformably apparently. The entire area near Mekhtar is formed of these beds which yielded belemnites in abundance, besides some ammonites.

This neocomian horizon is overlaid by a great series, which Mr. Smith was unable to divide further, but which seems to have varied a good deal lithologically; the middle of the series apparently contained nummulitic limestone beds, and the uppermost beds were capped by the white nummulitic limestone of the Spintangi beds. Some of the beds of this great series appear to be derived from volcanic material, and even basaltic rock was met with.

Later on, after returning from the Tochi pass, to which he was deputed on special duty, he traversed the country lying between Déra Gházi Khán and Ziárat. His observations were only made *en route* and consequently must be fragmentary. He reports that between Karwada to Mekhtar he traversed about 30 miles of middle and lower nummulitic rocks, sandstones and limestones with numerous shale partings. East of Mekhtar these beds rest apparently conformably on "belemnite beds" (upper cretaceous). From thence to some distance west of Loralai he observed all the rock facies which we already know to exist in those parts, *i.e.*, sections from the jurassic limestone to nummulitic, but he had no time then to further examine the country, the season being too far advanced. The high range north of the Sháhrig valley, generally known as the Kaliphát range and which rise

to upwards of 10,000 feet, seems to show in places a complete section beginning with the jurassic massive limestone, overlaid by cretaceous rocks and capped by the lower nummulitic limestone. The existence there of jurassic beds is an interesting fact.

During June Mr. Smith examined some of the high ground west of Ziárat, especially the Pil range, through which a fine section is laid bare by the tangi (defile) north of Mangi; the range is made up of a great thickness of massive limestone (about 3,000 feet), which he identifies with the jurassic beds seen further east, and which is overlaid by well-developed "belemnite beds" (*i.e.*, lower and upper cretaceous), the whole being covered by the hard grey lower nummulitic limestone.

Hills east of Sibi.—Lala Hira Lal, after handing over the Sukkur boring to the North-Western Railway authorities, was ordered to Baluchistán, and to survey the low ranges east of Sibi. He was engaged during May and June in geologically surveying the low hill ranges east and north-east of Sibi, which task was successfully accomplished. The rocks met with belong to the tertiary system and recent deposits. Upper nummulitic limestones were met with occasionally, but the rest seem to consist of very large thicknesses of Siwalik sandstones, shales and conglomerates only. Some fossils were collected by this officer, but apparently good specimens are very rare and as usual in those parts, the Siwaliks contain little more than fragmentary remains of vertebrates, amongst which are very few which will permit a specific determination.

Hills near Quetta.—Lala Kishen Singh was engaged during the last quarter of the year in examining the south-western extension of the Murdar hill near Quetta, which he found to consist of massive limestone, probably of jurassic and lower cretaceous age, the only clue to its structure apparently being a band of upper cretaceous belemnite beds. He also examined the northern end of the Chehiltan range; the section of it had already been worked out during previous field seasons. It includes strata from the upper jurassic to lower nummulitic age.

Tochi Pass.—Mr. Smith was deputed to join the Tochi delimitation camp during February and March, and he has furnished a short preliminary report,[1] the main features of which shew that the section seen along the Tochi route resembles closely that of the Sulaimán section, and that some of the rocks are very similar to those found in Baluchistán.

The section commences on its eastern limit with a series of Siwaliks, which dip eastwards under the recent deposits of the Bannu plain. The Siwaliks, both upper and lower, are of immense thickness, the lower beds alone showing a normal section of vertically dipping strata of 2 miles in length. Below them is a thin band, 170 feet, of white nummulitic limestone, beneath which follows a great thickness of shales and limestones, in which Mr. Smith did not discover any determinable fossils, but which he suspects to represent the entire middle and lower eocene divisions. The lowest beds of this sequence form an anticlinal ridge of dark grey unfossiliferous shaly limestone of unknown age. These lower tertiary rocks form a wide belt, some 30 miles from east to west, and include the Laram range. Near Mahomed Khél, the lower beds of the series become suddenly mixed with intrusive and also interbedded igneous rocks, chiefly diorites, gabbros, and serpentines. North of Sheranni this igneous series is overlaid by white nummulitic limestone

[1] Records, Vol. XXVIII, page 106.

and shales, and at Dotoi, 10 miles west of Sheranni, the same igneous series is overlaid by blue-slaty shales with thin nummulitic bands.

In some respects this description recalls the flysch-like series of rocks of the Kōjak and Peshin ranges.

Burma.
Dr. F. Noetling.
Dr. H. Warth.
Mr. H. H Hayden.

Oil.—The inquiry into the occurrence and nature of the earth-oil of the Yenangyoung neighbourhood has at last been brought to a successful close by Dr. F. Noetling, who was engaged on the work for several years but with interruptions. That officer returned from Burma in March of this year and has handed in a very voluminous and exhaustive report, fully illustrated with sections, views and maps now in the press.

Gems.—Dr. Warth was deputed to Burma to report on a tract of country north-west of Mogoung, where rubies had been discovered, and which area had been declared a "stone tract" by the Government of Burma. A long delay at Rangoon, owing to a medical examination which that officer had to undergo, prolonged the inquiry far into the hot weather and had therefore to be confined to the "stone tract" alone.

His report may be summed up as follows: The area consists of crystalline rocks, chiefly granitic and igneous, inclosing patches of metamorphic rocks, amongst which a crystalline limestone is especially noticeable, which contains the same minerals as found in the Mogok and Sagyin areas, and which is probably also here the original matrix of the rubies, which are now dug up by natives from the surrounding alluvium. The latter forms the "stone tract" proper, may be about ten square miles in extent, and does not seem to be very rich in gems.

Mr. H. H. Hayden was posted to Burma during this field-season, and he started work in the ruby-tract of the Sagyin hills during November. His researches carried out under somewhat trying conditions, which the dense vegetation aggravates, are of considerable interest. The main results obtained so far are as follows:—

The rocks of the area are chiefly of two kinds, namely, crystalline, consisting of gneiss and schists, and overlying the same, limestone which is considerably altered and contains many and interesting minerals, including spinel and ruby. The latter occur chiefly in a veinstuff which fills joints and fissures, and out of which the natives obtain the gems. One of the most interesting facts established by Mr. Hayden is that the limestone rests on the schists and gneiss, the junction being marked by the presence of a conglomerate associated with a limestone breccia, thus proving without doubt that this coarsely crystalline limestone is of sedimentary origin.

Publications.

Vol. II of Series XIII of the Palæontologia Indica has at last been published, and Dr. Waagen's description of the fossils from the Ceratite beds will henceforth form a standard work on the lower trias of the Salt Range.

The publication of this classic volume was so long delayed and so much new light has been shed upon the lower trias fauna of India within recent years, that a review of the results of Dr. Waagen's researches becomes imperatively necessary. I am informed that the learned Professor is preparing such a summary, which will probably be first published in Europe.

Of the Series XV on Himálayan Fossils, part 2 of Vol. II has already appeared, descriptive of the Cephalopoda of the Muschelkalk. The material which Dr. Diener had at his disposal, which includes all the specimens collected from those beds in the Himálayas up to date, is so complete that we are in a position to correlate these beds with perfect accuracy. It is a matter of especial satisfaction to me that the examination of these interesting fossils has confirmed my division of the trias of the Central Himálayas, founded as it was, chiefly upon stratigraphical grounds.

Part 1 of the same volume, on the Cephalopoda of the lower trias by the same author, is in a forward condition and ought to be published at an early date. All the plates illustrating the same are completed and the manuscript is ready for the press.

Dr. Noetling has prepared several parts of a new Series XVI of the Palæontologia Indica to illustrate the fauna of Baluchistán and North-Western frontier, which await only the completion of the plates, to be issued.

Several memoirs are in course of publication; part 1 of Vol. XXVII on "Marine fossils from the Miocene of Upper Burma" by Dr. Noetling has been published, and part 2 is in the press.

Gondwanas in South America.

A discovery of vast interest to Indian Geologists has been made during the year to which I must allude here; it is the discovery of a Gondwana flora[1] in coal-bearing deposits in Argentina, made by Dr. Kurtz, Professor at the University of Cordoba. The flora, with several species identical with such out of the Indian Gondwanas, occurs in beds, which overlie,—though in what manner is not known yet,—a series of beds containing a true carboniferous (Culm) flora. But the most interesting fact is that in Argentina *Neuropteridium validum* is found in the same beds with *Lepitodendron*, as I am informed by Dr. Kurtz, who has promised to give me further and more concise particulars.

Museum and Laboratory.

Mr. Holland, the curator, was absent on privilege leave from March 12th to June 27th and later on duty at Naini Tal, from which he returned on 13th November, but he has since been engaged in arranging the rock and mineral collections belonging to the Department.

The collection of rocks now amounts to over 16,000 specimens and they have been registered and partially arranged. Satisfactory progress has been made also in the classification and description of the collection. The miscroscopic characters of about 500 specimens of the crystalline rocks have been worked out, which will enable Mr. Holland to form a preliminary sketch of the classification of this group, which, though so largely represented in India, has hitherto received little more than superficial attention in the field, when as in previous years, the specimens in the collection were found to be types new to petrology, or were found to offer important evidence concerning unsettled petrographical problems. Mr. Holland has taken the opportunity, where possible, of utilizing the college vacations for the purpose of tracing out their field relations, and of collecting fresh material for confirming or correcting the microscopic work in the laboratory. As a result of work of this nature, the examination of the field relations of the new types of

[1] Records, Vol. XXVIII, p. 111.

peridotites discovered by Mr. Holland and referred to in my last annual report has enabled him, in conjunction with Dr. Saise, to completely describe them and to revise a map showing the nature and distribution of the intrusive rocks in, and the crystalline series around, the coal-field of Giridih.[1]

The interesting forms of metamorphism displayed by the crystalline rocks around this coal-field having been found to result in the production of garnets in pyròxenic type, the remaining pyroxenic rocks of India, and specially those of the Madràs Presidency, whose presence and wide distribution in Southern India were first noticed by Mr. Holland in 1892, have been examined with special reference to the origin of this mineral which is so remarkably abundant in this country. In a paper contributed to the current number of the Records Mr. Holland has traced out the development of the garnets in these pyroxenic rocks, and, from the evidence obtained from widely separated areas in India, he concludes that the reaction-borders often confused with Kelyphite, and occurring so frequently associated with the garnets of pyroxenic rocks, represent a stage in the development, and not, as has generally been supposed, in the destruction of garnets. Mr. Holland has contributed another paper to the same number of the Records in which he has from the evidence of the specimens collected by himself in Madras combated the views expressed by Mr. Lacroix concerning the nature of the acicular inclusions giving rise to the phenomena of asterism, so frequently characteristic of Indian gem-garnets.

Amongst the specimens of interest added during the year are eight new meteorites.

Mr. Holland reports most satisfactorily on the work done during the year in the laboratory and museum by his assistant, Mr. T. R. Blyth.

Library.

The additions to the library during the past year amount to 1,949 volumes, of which 1,149 were acquired by presentation and 800 by purchase.

C. L. GRIESBACH,

Director, Geological Survey of India.

CALCUTTA,

The 31st January 1895.

[1] Records, XXVIII. p. 121.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1895.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—Adirondack Survey.
" New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—Johns Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Kon. Natuur Kundige Vereeniging in Nederl.—Indie.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
" K. Preuss. Acad. der Wissenschaften.
" K. Preuss. Geologische Landesanstalt.
BOLOGNA.—Reale Accademia delle Scienze dell' Istituto.
BOMBAY.—Meteorological Department, Government of Bombay.
" Natural History Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australia.
" Royal Society of Queensland.
BRUSSELS.—Academie Royale des Sciences.
" Société Belge de Geographie.
" Société Belge de Geologie de Paleontologie et d' Hydrolog.
BUDAPEST.—Kön. Ungarische Geologische Anstalt.
" Ungarische National-Museum.
BUENOS AIRES.—Acad. National de Ciencias en Cordoba (Republica Argentina).
BUFFALO.—Society of Natural Sciences.
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
" Asiatic Society of Bengal.
" Calcutta University.
" Editor, The Indian and Eastern Engineer.
" Meteorological Department, Government of India.
" Survey of India.
CAMBRIDGE.—Philosophical Society.
" University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CANADA.—Hamilton Association.
CHRISTIANA.—Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Academie Royale des Sciences.
" Kong. Danske Videnskabernes Selskab.
DEHRA DUN.—Great Trigonometrical Survey.

DES MOINES.—Iowa Geological Survey.
DIJON.—Academie des Sciences, Arts et Belles-Lettres.
DRESDEN.—Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
EDINBURGH.—Geological Society.
" Royal Scottish Geographical Society.
" Royal Scottish Society of Arts.
FREIBURG.—Naturforschende Gesellschaft.
GENEVA.—Société de Physique.
GLASGOW.—Glasgow University.
GOTHA.—Editor, Petermann's Geographische Mittheilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALLE.—Naturforschende Gesellschaft.
" Academia Cæsarea Leop.-Carol. Naturæ Curiosorum.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LIÈGE.—Société Géol. de Belgique.
LILLE.—Société Géologique du Nord.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—Iron and Steel Institute.
" Linnean Society of London.
" Royal Geographical Society.
" Royal Institute of Great Britain.
" Royal Society.
" Society of Arts.
" Zoölogical Society.
MADRID.—Reale Academia de Ciencias.
" Sociedad Geografica de Madrid.
MANCHESTER.—Geological Society.
" Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
" Royal Society of Victoria.
MILAN.—Societá Italiana di Scienzé Naturali.
MOSCOW.—Société Imp. des Natur.
MUNICH.—Kon. Bayerische Acad. der Wissens.
NAPLES.—Reale Academia delle Science Fisiche e Matematiche.
NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
" Editor, American Journal of Science.
NEW YORK.—Academy of Sciences.
OTTAWA.—Geological and Natural History Survey of Canada.
" Royal Society.
OXFORD.—University Museum.
PARIS.—Department of Mines.
" Editor, Annuaire Géologique Universel.

PARIS.—Ministere des Travaux Publics.
„ Museum d' Histoire Naturelle.
„ Société de Géographie.
„ Société Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Scienze.
„ „ Comitato Geologico d' Italia.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Académie Imperiale des Sciences.
„ Comité Géologique.
„ Russische Kaiserliche Mineralogische Gesellschat
SALEM.—American Association for the Advancement of Sci
SAN FRANCISCO.—California Academy of Sciences.
S. PAULO.—Commissao Geographica e Geologica.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—Kongliga Svenska Vetenskaps Akadémie.
SYDNEY.—Australian Museum.
„ Department of Mines and Agriculture, New South Wales.
„ Geological Survey of New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TOKIO.—Deutsche Gesellschaft für Natur und Volkerkunde.
TURIN.—Osservatorio della R. Universita di Torino.
„ Reale Accad. delle Scienze di Torino.
UPSALA.—Upsala University.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissens.
„ K. K. Geographische Gesellschaft.
„ K. K. Geologische Reichsanstalt.
„ K. K. Naturhistorisches Hof-Museum.
WASHINGTON.—Smithsonian Institution.
„ United States Department of Agriculture.
„ „ „ Geological Survey.
„ „ „ Mint.
WELLINGTON.—Mining Department, New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.

ZÜRICH.—Naturforschende Gesellschaft.

The Governments of Bengal, Bombay, India, Madras, N.-W. Provinces and Oudh, and the Punjab.

The Chief Commissioners of Assam, Burma, and the Central Provinces.

The Resident, Mysore.

On the Acicular inclusions in Indian Garnets. By THOMAS H. HOLLAND, A. R. C. S., F. G. S., *Deputy Superintendent, Geological Survey of India.*

I. INTRODUCTION.

1. In his detailed description of the rocks collected in 1819 by Leschenault de la Tour in the South of India, M. A. Lacroix has figured and described, in a basic pyroxenic gneiss, garnets containing acicular inclusions which he considers, from their high, positive, double refraction and straight extinction, to be rutile.[1] To the arrangement of these inclusions in systems mutually intersecting at angles of 60° M. Lacroix ascribes the asterism so frequently exhibited by Indian garnets.

2. During my work in South India I have found at various places in the Madras Presidency garnets in pyroxenic rocks of all degrees of acidity from granites to pyroxenites. In the smaller masses which rise above the plains at Pallavaram near Madras, at Mailam in South Arcot district, at Wallavanad in Travancore and in the Madura district the garnets, as well as the associated constituents of the rocks, are often free of these inclusions, but the rocks in the Nilgiri hills, which attain heights of 8,000 feet, and in the Shevaroys of Salem district are crowded with minute hair-like inclusions which appear in the quartz, felspar and garnet alike, whilst the pyroxenes, which are constant constituents throughout the whole series of these rocks, are schillerized with plates and rods like those in the well-known hypersthene of Paul's Island.

3. The occurrence of these hair-like inclusions in an isotropic mineral like garnet affords special facilities for the investigation of their optical properties. Whilst their characters agree in so many respects with those described by Lacroix, I find that instead of being referable to a uniaxial mineral like rutile they exhibit unmistakeable characters of a mineral crystallizing in the monoclinic system, and thus, whilst exhibiting in some sections extinction parallel to the long axis of the needles (orthopinacoidal sections), in other cases (clinopinacoidal sections) extinction angles as wide as 39° have frequently been measured.

II. CRYSTALLOGRAPHIC DISPOSITION OF THE NEEDLES.

4. The disposition of these needles with reference to the crystallographic orientation of their host, the garnet, is of an extremely interesting nature. Not only are the needles arranged with a constant relation between the direction of their long axes and the forms of the cubic system in which the garnet crystallizes, but the plane of symmetry, and consequently the orthopinacoidal plane, of each minute needle are arranged in definite crystallographic positions within the garnet—a circumstance quite in agreement with the definite crystallographic disposition of the products of schillerization in felspars, pyroxenes, olivines and other minerals which have been described on several occasions by Professor Judd. I regard these needles in the garnet, and what are probably the same things in the associated felspars, pyroxenes and quartz, as secondary in origin and belonging to the same

[1] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 311, and *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 176.

class as the inclusions which according to Professor Judd are the cause of the phenomena of schillerization.

5. Besides the sections in which the acicular inclusions appear to intersect one another at various angles I have found some which can be arranged in three distinct classes, and in which the disposition of the needles is capable of a very simple crystallographic explanation.

If we assume the long axes of the inclusions to be parallel to the long diagonal of the rhombus forming the face of the rhombic dodecahedron—the form in which the garnet crystallizes—or, which is the same thing, parallel to the solid edges of the octahedron, we obtain definite intersections exhibited in sections cut parallel to the octahedron, the cube and the rhombic dodecahedron respectively as follows:—

(1) In sections parallel to the *octahedron* there are three sets of needles lying in the plane of section and intersecting one another at angles of 60° (system *a*).

(2) Sections parallel to the *cube* exhibit two sets of needles lying in the plane of section and crossing one another at right angles (system *b*). Two other sets (system *c*) lying apparently at 45° to those belonging to system *b* will be seen, when examined with high powers, to be lying oblique to the plane of section, and consequently will as a rule appear to be shorter than those of system *b*, their maximum length in fact can never exceed

$$\sqrt{2} \times \textit{thickness of section.}$$

(3) Sections parallel to the *rhombic dodecahedron* display two systems of inclusions. One system (system *d*) lies in the plane of section and is crossed by a second system (system *e*) at an apparent angle whose tangent is $\sqrt{2}$, that is 54°16′. The two sets of system *e* consequently intersect one another at angles of $2 \times (90° - 54°16') = 71°28'$, and its supplement.

III. OPTICAL ORIENTATION OF THE NEEDLES.

6. As the needles are monoclinic in crystallization and their lateral as well as vertical axes have a constant crystallographic disposition within their host the garnet, the optical characters exhibited by these three classes of sections are also different, and, assuming the long axis of each needle to be its vertical crystallographic axis, the positions of the orthodiagonal *axis* and the clinopinacoidal *plane* are easily determined.

(1) Sections of garnet cut parallel to the face of the cube and examined between crossed Nicols show system *b* lying in the plane of section and exhibiting an extinction angle as great as 39°. System *c*, however, apparently intersecting these at an angle of 45°, and seen by high powers to be lying oblique to the plane of section, exhibit straight extinction. Taking the plane of symmetry to be the optic axial plane, as is usual in monoclinic minerals, this plane must be parallel to the cube faces and exhibit the maximum extinction angle.

(2) In sections parallel to the octahedron all the needles (which have been referred to as system *a*) are cut obliquely to the plane of symmetry, and the extinction angle is consequently somewhere between zero and the maximum. Numerous measurements made on these sections gave results varying between 18° and 25°.

(3) Sections parallel to the rhombic dodecahedron give straight extinctions for system *d*, and oblique extinctions less than the maximum for system *e*.

7. The monoclinic acicular inclusions in the garnets are thus arranged as follows:—

Vertical axis of the needle parallel to the *edge of the octahedron* of the garnet.
Orthopinacoid parallel to the *rhombic dodecahedron*.
Clinopinacoid parallel to the *cube*.

That is to say, they are arranged with their orthopinacoidal faces lying on the cleavage planes of the garnet and with their long (vertical) axes parallel to the long diagonal of the rhombus. I am indebted to my colleague Mr. H. H. Hayden for having verified each of these conclusions in thin sections of garnetiferous pyroxenic rocks collected by myself at Nagaramalai, near Salem, and at Coonoor in the Nilgiri Hills.

8. Diller has described what appear to be similar inclusions in the garnets of a loose fragment of granulite found near the peridotite of Elliott County, Kentucky. According to Diller these inclusions are arranged at angles of 45° to one another, and are distinctly monoclinic with a maximum extinction angle of 30°.[1] If my conclusions are correct these inclusions should correspond to the two systems of needles *b* and *c* which I have recognised in sections cut parallel to the face of the cube (para. 5).

9. Lacroix states that the needles which he found in the garnets of the Salem pyroxenic gneiss show the positive double refraction of rutile. I find on examination of the monoclinic needles in my own specimens with a quartz-wedge that the axis of minimum optical elasticity $\mathfrak{c}$ lies at 39° to the vertical crystallographic axis *c*; there would therefore be an appearance of thickening on placing a quartz wedge with its axis parallel to an orthopinacoidal section. The straight extinction of such a section and its behaviour under the quartz-wedge would thus agree precisely with the characters of a uniaxial positive mineral like rutile; but that the mineral which forms these needles is biaxial is demonstrated beyond all possible question by the very wide extinction-angle and by the cross-sections which, although mere points, show strong double refraction.

10. I have, however, found needles of a mineral which show the straight extinction and strong, positive, double refraction of rutile in the augite-diorite forming the main mass of Parasnath in Bengal. But these are invariably shorter and form clusters in the centre of the garnet without displaying any recognisable regularity of crystallographic disposition within their host. Even in the same section they are not likely to be mistaken for the monoclinic needles that characterise the garnets in the Madras pyroxenic rocks.

11. According to Lacroix in hexagonal sections of these garnets the inclusions are arranged with parallelism to the sides of the hexagon; but unfortunately the

[1] *Bull. U S. Geol. Surv.*, No. 38 (1887), p. 27.

figure given by him does not show the crystal outlines with sufficient clearness to illustrate this statement. Although as the result of my investigations, I should not expect this to be the case, I have never found a garnet in the Madras rocks exhibiting its proper crystalline outlines, and have consequently been unable to make a direct test of this statement.

12. Whilst it is not possible to determine with certainty the species of mineral which forms the inclusions under consideration, their optical characters, so far as they can be investigated, are suggestive of those of sphene, in which also the axis $\mathfrak{c}$ meets the vertical crystallographic axis c at about an angle of 39°, although of course it does not necessarily follow that the vertical axis in this mineral would follow the direction of greatest elongation. A chemical test, however, made by Mr. Hayden and myself showed that the garnets contain small though unmistakeable traces of titanium.

13. The quartz and felspar which accompany the garnet, or occur in the associated pyroxenic rocks in the Nilgiri and Shevaroy hill-masses, are often crowded with fine hairs of a nature presumably similar to those occurring in the garnets. There seems little doubt that the blue colour of the quartz and the moonstone opalescene, which so frequently characterises the felspar of the more coarsely-grained charnockites, are due to the presence of these inclusions, whose definite crystallographic disposal suggests their secondary origin in common with the ordinary products of schillerization.

14. It is not without interest that in garnets with striated faces the striations are parallel to the longer diagonal of the rhomb faces, which I have shown to be the position of the hair-like inclusions, and according to Descloizeaux asterism has generally been observed in garnets having such striated faces. There seems little doubt, as Lacroix suggests, that the asterism exhibited by some Indian garnets is due to the fine hair-like inclusions which exhibit such a perfectly symmetrical disposition not only of the long axes but also of the lateral axes of crystals so minute that their cross-sections, even with high powers, appear as mere points of light in the isotropic ground-mass of their host the garnet. I can recollect no prettier illustration of Professor Judd's generalization concerning the secondary changes brought about by agents of statical metamorphism acting on the minerals of deep-seated rocks and giving rise to the phenomena which he has described under the name of schillerization.

CONCLUSION.

15. The hair-like inclusions which give rise to the phenomena of asterism in Indian garnets are not rutile as stated by Lacroix, but are monoclinic in crystallization, exhibit a high double refraction and show an extinction angle as wide as 39° ($\mathfrak{c} \wedge c$) to the long axes of the needles. They are arranged with remarkable regularity of crystallographic disposition within their host the garnet, having their long axes parallel to the edge of the octahedron, their orthopinacoidal faces parallel to the face of the rhombic dodecahedron and their clinopinacoids parallel to the cube. They are considered to be secondary in origin along with the similar hair-like inclusions which give rise to the phenomena of schillerization in the associated blue quartz, moonstone and hypersthene of the pyroxenic rocks in which the garnets occur.

On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks, by THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With plate 1.)

CONTENTS.

A. THE ORIGIN AND GROWTH OF GARNETS.

I.—INTRODUCTION.

1. Garnets occur in rocks of every degree of acidity from granites to peridotites, and the ordinary iron-alumina garnet is well-known as one of the commonest amongst the products of the contact-metamorphism of aluminous rocks. Whilst its secondary origin can be so easily proved in the slates and schists which have been changed by proximity to igneous intrusions, the origin of garnet when a constituent of igneous rocks and of the crystalline types generally cannot always be so satisfactorily determined. As a rule, it is impossible to settle from the rock specimen *per se* whether the garnet is a primary or a secondary constituent; but from its more frequent occurrence in the gneissose crystallines than in rocks of massive habit, it is more generally grouped—though seldom with better reason than analogy—amongst the constituents of secondary origin.

2. The very prevalent occurrence of garnets amongst the pyroxenic granulites of South India, to which I have paid considerable attention during the last four years, has led me to make a more widely extended investigation amongst the garnetiferous rocks of this country with a view to obtaining more exact evidence concerning the origin of this mineral. I have considered this investigation the more necessary on account of the fact that Dr. J. Lehmann, in his classical work *Die Entstehung der altkrystallinischen Schiefergesteine,* has recorded the frequent

occurrence of garnet in the pyroxene-granulites of Saxony, which appear in many respects to closely resemble the Madras series. But whereas Dr. Lehmann considers the garnet, where it is surrounded with reaction-borders resembling Schrauf's kelyphite, to be passing into pyroxene, I have been led to a totally different conclusion with regard to the pyroxenic rocks which I have studied in India, and in which reaction-borders, apparently quite similar in character, are frequently found between the pyroxene and garnet. These, it seems to me, afford, so far as the Indian rocks are concerned, most decisive evidence in favour of regarding the garnets as secondary in origin and derived from the pyroxene which was amongst the original constituents of the rock.

3. That this conclusion is capable of wider application cannot of course be claimed, but it seems to me that in many cases where reaction-borders around garnets have been described, the precise evidence concerning the *direction* of the change might have been studied with advantage. The mere fact that the proportionate area of garnet core and reaction-border varies from cases in which the border is proportionately narrow to those in which the garnet forms merely a small nucleus, or even totally disappears, is no proof whatever that the reaction-border is formed at the expense of the garnet. As the garnets are most irregular in shape every one of these stages might be obtained by sections through the centre, near the surface, or along a flat face of the crystal which is so surrounded by a reaction-zone.

4. It should also be understood that these conclusions have no bearing whatever on previously-stated views concerning the nature of the *kelyphite* rims which surround the pyropes described in many peridotites, nor has it necessarily any connection with the evidence obtained from the Saxon pyroxenic rocks; but as I find it necessary to consider the garnets of secondary origin in all the pyroxenic rocks which I have so far studied in India, it may be advisable to state in detail the steps by which I have been led to this conclusion, the more so because the processes by which pyroxenes are converted into garnets seem to have been described, so far as I can find, in one case only. Brauns in 1888 described the formation of a lime-iron garnet in the palæopicrite of Bottenhorn as an alteration form of augite in which chemical analysis indicated a removal of alumina.[1] Beside this the literature at my disposal in Calcutta has not revealed a single case of a garnet formed from pyroxene, although the contrary has been asserted in more than one instance.

5. The evidence obtained from the same material also offers a very simple explanation of the origin of the *micropegmatitic intergrowths* of garnet with such white minerals as quartz and felspar. The micropegmatitic structure is consequently in these instances considered to be of secondary origin.

II.—The Reaction-borders of Garnets.

6. The fibrous zones which surround the pyrope in olivine-rocks were first described by Schrauf as a primary constituent of pyrogenic origin to which he gave the name *kelyphite*,[2] but von Lasaulx showed that these borders are in some cases,

[1] *Zeitschr. d. d. geol. Ges.*, Vol. XL (1888), p. 475.

[2] *Zeitschr. f. Kryst.*, Vol. VI (1882), pp. 333 and 358; also *Neues Jahrb. f. Min.*, 1884 (II), p. 21.

mixtures of different minerals, generally members of the pyroxene-amphibole group and of secondary origin.[1] Becke found similar borders around the garnet of Steineck composed of picotite and several members of the pyroxene-amphibole group.[2] Diller found the pyropes in the Elliott County peridotite composed largely of biotite,[3] whilst von Camerlander described in the granulites of Prachatitz a micropegmatitic intergrowth of augite and plagioclase forming a border around garnet.[4]

7. Seeing kelyphite has been found to be a mixture of minerals so variable in composition, and especially as in all cases described it has been regarded as a product of the *destruction* of garnet by reaction with olivine or pyroxene, either during or subsequent to consolidation, I shall avoid altogether the use of the term in connection with the fibrous zones which surround the garnets in the cases about to be described, for these I consider to represent the products not of destruction but a stage in the *development* of the garnets with which they are associated. They will be referred to therefore merely as *reaction-borders.*

8. Lacroix has described radiate zones composed of micropegmatitic intergrowths of hornblende and felspar around garnets in an eclogite from Gerscao-en-Plounevez, Finisterre.[5] He has also figured and described a radiate fringe around garnets in a pyroxenic rock from the Salem district,[6] but has offered no explanation of the origin of the phenomena in these cases.

9. The reaction-borders measure about ·04 mm. across and are composed of two distinct layers, an inner (garnet side) layer of colourless mineral in which clavulate and vermiform pieces of a pale green actinolite are arranged approximately perpendicular to the garnet surface, giving with the low powers an appearance of radiate fibrous structure. The colourless mineral with crossed nicols shows colours about equal to those of the felspars in the same sections, and display lamellar twinning bands. The outer zone consists of a narrow band of magnetite-granules forming a margin to the pyroxene.

III.—THE ROCKS IN WHICH THE GARNETS OCCUR.

10. The specimens which it is proposed to select as examples for the study of the origin and growth of garnets have been obtained in two principal areas separated from one another by distances of at least 700 miles.

The first group of rocks occurs as large dykes and bosses of diorites amongst the gneisses and schists of Chota Nagpore and the Sonthal Pergunnahs in Bengal. These rocks by their resistance to agents of denudation are conspicuous as hummocks and even high hills in the neighbourhood of our coal-fields. As they can often be traced up to the boundary faults, but are never intruded into the stratified rocks of Lower Gondwana age within the field, it is presumed that they are older than the deposits of that system. In nearly all cases which I have examined, these can be shown to have been derived from original pyroxene-plagioclase rocks, which show

[1] *Sitzungsber. der Niederrhein. Ges. f. Natur und Heilkunde*, 3rd July, 1882.
[2] *Tschermak's min. u. petr. Mitt.*, Vol. IV (1882), p. 324.
[3] *Bull. U. S. Geol. Survey*, No. 38 (1887), p. 15.
[4] *Jahrb. d. k. k. geol. Reichanstalt*, Vol. XXXVII (1887), p. 133.
[5] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 142.
[6] *Ibid.*, p. 322; also *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 183.

a strong family likeness in the field and apparently belong to a petrographical province of pre-Gondwana age. A closer examination reveals some very interesting differences in the changes which they have suffered by the various agents of metamorphism.

The dynamical metamorphism to which some of these rocks have been subjected has resulted in the production of well-foliated epidiorites and hornblende-schists. In others, where earth-movements have been preceded by the production of sodic chloride inclusions along the twin-planes of the felspar, scapolite is conspicuous amongst the new minerals;[1] but those in which garnets have developed show slighter, though decided, signs only of deformation by dynamical agencies. To this last mentioned group belong some dykes at Mongrodih near Giridih, some rocks collected by the late Mr. Fedden in the Ijri valley of Manbhúm, and the main mass of Parasnath, a sacred hill rising to a height of 4,479 feet on the borders of the Hazaribagh and Manbhúm districts.

11. The second group of rocks forms the great hill-masses of the Madras Presidency——the Nilgiris, Shevaroys, Palnis, Anaimalais, Western Ghats and Cape Comorin. These rocks, although varying so widely in silica percentage from acid granites to pyroxenites and even peridotites, present a most remarkable and unmistakeable family likeness in the field.

Microscopic examination shows that without a single exception the unaltered forms are characterized by the presence of a rhombic pyroxene approaching hypersthene in composition, which may occur in very small proportions, as in charnockite, or may make up almost the entire rock, as in some pyroxenites. The hypersthene may be the sole representative of the group of ferro-magnesian silicates, or it may be accompanied by augite, hornblende, biotite, graphite and garnet. Sometimes it is replaced entirely by garnet in rocks which I hope to show are beyond question altered forms of the pyroxenic series.

IV.—EVIDENCES OF THE GROWTH OF GARNET.

12. The special features in the structure of these rocks which appear to corroborate one another in the evidence they offer in favour of the growth of garnet at the expense of the pyroxenic constituent, may be considered under the following heads :—

(1) Limitation of the reaction-borders.
(2) Uralitization (amphibolization) of the pyroxenes near the garnets.
(3) Schillerization of the pyroxenes.
(4) Parallel growth of adjacent garnet crystals.
(5) Field relations of the pyroxenic and garnetiferous rocks.
(6) Chemical changes involved in the formation of garnet.

1. Limitation of the Reaction-borders.

13. The reaction-border appears wherever the garnet meets the pyroxene or, more strictly speaking, its paramorph hornblende, but there is not a trace of it where the garnet comes in contact with felspar or quartz. This of course only shows that there is some kind of reaction between the garnet and the pyroxene;

[1] See Holland and Saise. "On the Igneous Rocks of the Giridih (Kurhurbaree) Coalfield and their Contact Effects." *Rec. Geol. Surv. Ind.*, Vol. XXVIII (1895), p. 121.

but the fact that opposite the pyroxene the garnet bulges out to meet the latter is a circumstance which would naturally be expected if we regard the pyroxene as the source of the garnet material.

Fig. 1 illustrates a case in which the garnet, fringed by a reaction-border, bellies out in this manner opposite the pyroxene, whilst colourless felspar fills a bay in the garnet, which at this point is without a reaction-border. This case will be referred to again in describing the origin of the micropegmatitic intergrowth of garnet and felspar.

2. *Uralitization (Amphibolization) of the Pyroxenes near the Garnets.*

14. The formation of these reaction-borders between the garnet and pyroxenes seems to be always accompanied by the formation of hornblende, which lies between the unaltered augite and the reaction-zone, and which seems to be a preliminary change in the augite necessary to the development of the garnet. In parts of the rock free of garnets the augites show the characteristic signs of incipient uralitization in the form of green pleochroic patches. This conclusion is further supported by the fact that occasionally pale green augites, which do not show the slightest sign of amphibolization, abut against the garnet without a trace of a reaction-border.

If the opposite change—that is the formation of pyroxene from garnet—were in progress, we should have in this instance a case of the formation of hornblende from garnet followed by the transformation of the former mineral into augite—a change under the circumstances quite contrary to experience. The alteration of the pyroxene near the garnets is only an advanced stage of that which is seen to be commencing in nearly all the augites and is a case of ordinary amphibolization. That such is the real direction of change is even more clearly demonstrated by the next point of evidence.

(3) *Schillerization of the Pyroxenes.*

15. The original augite, in the rocks for instance from Parasnath and the Ijri valley, are darkened, often almost blackened, with minute rods and plates regularly arranged as in diallage and forming an ordinary example of schillerization, whilst the hornblende, which has been derived from this augite, is free of such inclusions. The schillerization of the ferromagnesian constituent must, therefore, have occurred before its amphibolization, and as the amphibolization appears to be a constant accompaniment of, and probably an essential preliminary to, the development of the garnet, the schillerization must have occurred also before the formation of the latter mineral. If the opposite change had occurred we should have a case of the transformation of garnet into a clear green hornblende, followed by the change of green hornblende into schillerized augite. In view of Professor Judd's explanation of the phenomena of schillerization such an alternative explanation of the facts may be safely rejected without further discussion. There is no doubt that the amphibolization of the schillerized augite is accompanied by the absorption of the secondary ferruginous products, the iron of which enters into the composition of the hornblende, and then of the final product, garnet.

The relative positions of the minerals in the rock are thus—

Schillerised Augite.	*Clear green Hornblende.*	*Reaction border.*	*Garnet.*

$\longrightarrow$

(4) *Parallel growth of adjacent Garnet-crystals.*

16. In the Manbhûm rocks the large garnets are clear and pink in their centres, but towards the margin, where they approach the ferromagnesian mineral, numerous vermiform, radially-arranged cavities destroy the transparency of their selvages. Beyond—that is, outside—these zones of cavities the crystal-outlines of the garnet can be traced, and these by repeated alternation of forms give rise to saw-like outlines like those which characterize a section of "Babel" quartz. Beyond this crystal-outline there is a zone of felspar and vermiform actinolite which often penetrates the crystal limits and communicates with the vermiform cavities forming the zone immediately inside the faces of the garnets. It is evidently along this zone that the change is proceeding.

Here and there clusters of minute garnets are to be seen which offer equally instructive evidence. These are often so small that they are darkened throughout by the vermiform cavities and indeed in many cases are but imperfect rhombic dodecahedral clearings in the hornblendic material, but in which with the higher powers of the miscroscope it is not difficult to pick out the isotropic garnet from the imperfectly cleared dirt and cavities. From this stage, as the clear central area enlarges and shows the garnet pink colour, we can trace every gradation up to the largest crystals in which this selvage only covers a small fraction of the total area of the section. It is clear that as growth proceeds the proximal ends of the vermiform cavities are gradually obliterated by deposition of garnet substance in crystallographic continuity with the skeleton, and so the central area grows simultaneously with the extension of the crystal borders amongst the hornblendic material around.

Wherever the garnet comes into contact with felspar instead of a ferro-magnesian mineral, there is no such development of crystal-form nor is there a zone of vermiform cavities: the clear pink garnet is simply moulded on to the older felspar. It is only opposite the pyroxene—that is where growth can proceed without interruption—that the crystal-outlines occur. If the reaction-zones represented decom position of the garnet we should naturally expect irregular corrosion of the crystal, whereas we have well-shaped crystals and this only where the reaction-borders occur.

Wherever patches of small young garnets are found growing around isolated centres, it is frequently found that several of them may develope with crystallographic parallelism and on meeting form one large crystal. This interesting occurrence is more strikingly exemplified by patches of small crystals which form in the neighbourhood of a large one with their faces parallel to those of the large crystal and consequently to one another (Fig. 3).

17. The parallel growth of these minute crystals around the larger and probably older individuals forms a very pretty illustration of the influence a crystal exerts beyond the limits of its own faces. In a case where free movement of the material is possible, as in molten material, the surrounding magma is impoverished by removal of the crystallizing substance, and in this way we get in the tachylytes a clear zone of glass around each magnetite-crystal, whilst beyond this zone the glass is darkened by magnetite-dust. The pink film around the growing cobalt-chloride crystals in a blue solution of the salt forms a still more striking illustration of what O. Lehmann calls *der Hof des Krystalles.*[1]

When crystal-growth takes place *after* the consolidation of the substance and as

[1] *Zeitschr. f. Kryst.*, Vol. I, p. 99.

a secondary change, the "sphere" of the crystal influence is indicated, as might be expected, not by removal of material, but by parallel development from isolated centres confined to fairly well-defined limits around the central crystal, as exemplified by the beautiful instances of garnets in the Manbhúm pyroxenic rock.

18. The growth of garnets in these pyroxenic rocks which show no signs of exposure to extreme temperatures since their primary consolidation, is comparable to the well-known secondary enlargements of such minerals as hornblende (Becke, Van Hise, Harker, Bonney), augite (Van Hise, Merrill), plagioclase-felspar (Judd) and orthoclase (Haworth, Holland).

(5) *Field relations of the Pyroxenic and Garnetiferous rocks.*

19. One of the most interesting types of the South Indian pyroxenic rocks is a granite composed essentially of quartz, orthoclase largely in the form of microcline, hypersthene, and always considerable quantities of opaque iron-oxides. This rock which possesses a striking individuality both in the field and under the microscope, I have described elsewhere under the name of *charnockite.*[1] As a rule it is compact and brittle with a very characteristic dark grey or green clour; but near its junctions with the norite, with which it is always associated, it changes very rapidly, almost suddenly, to a dirty white colour, becomes granular in structure, crushes easily under the hammer, shows a slight but distinct foliation, and is seen then to be sprinkled with garnets.

Under the microscope these changes in macroscopic characters are seen to be accompanied by corresponding changes in microscopic structure. Instead of the perfect granitic structure which characterises the unaltered rock, the weaker minerals are seen to be crushed and surrounded with selvages of mylonite, whilst the quartz-crystals show very marked "undulose" extinctions which invariably characterise rocks subjected to pressure.

But that this is an altered form of charnockite there would be little doubt even if the fact could not be demonstrated beyond question in the field. The quartz, microcline and black iron-ores are recognisable in precisely the same proportions, but instead of hypersthene there are irregularly-shaped, pink garnets, which bear to the rest of the rock a proportion, so far as determinable by sections, identical with that of the original hypersthene. That the garnets in this case have been formed from the hypersthene as one among the unmistakeable results of the metamorphism of charnockite there can be no question. Examples of this kind are most beautifully illustrated in the low hills immediately east of the railway station at Pallavaram near Madras, and at Coonoor in the Nilgiri hills.

Simultaneous with the appearance of a granulitic structure and other signs of pressure, the hypersthene has given place to pink garnet. A similar association has been recorded by Mr. Teall in the gneissose granite of Beinn Vuroch, where the ordinary granite differs from the gneissose forms in the presence of garnet accompanied by a granulitic structure in the latter varieties.[2]

I have recently traced up a dyke near Kidgeree, in the Hazaribágh district, from a compact pyroxenic type to a foliated garnetiferous one in which the pyroxene has completely disappeared.

[1] *Journ. As. Soc. Beng.*, Vol. LXII (1893), p. 162.
[2] Brit. Petrography (1888), p. 326.

6. *Chemical changes involved in the formation of Garnet.*

20. It would of course be extremely interesting to trace the precise chemical changes which accompany the transformation of pyroxene into garnet; but the latter mineral is so intergrown with felspar and crowded with inclusions that separation of sufficient clean material for chemical analysis was found to be impracticable.

21. There is no doubt, however, that the change is not a simple paramorphic one. The garnet contains less silica and probably a smaller proportion of lime and alumina than the pyroxene from which it is derived. The excess of silica combines with the alumina, lime and small quantities of alkalies present in the pyroxene to form the plagioclase felspar which is so frequently intergrown in a pegmatoidal manner with the garnet. The chemical constituents of the pyroxene are thus re-arranged to form two minerals—one more basic and the other more siliceous than the original. As the more garnetiferous portions of the slides invariably contain more felspar than the portions where the pyroxene has suffered no change, the microscopic evidence confirms this conclusion.

22. Another microscopic character which has a direct bearing on the chemical question is the depth of colour of the garnets. In the Madras rocks the colour of the pink garnet is most strikingly similar to the pink of the highly pleochroic hypersthenes in the same slide, so much so that without moving the polariser sections of the latter mineral might very easily be mistaken for garnets. In some quartz-biotite-norites from Isa Pallavaram, near Madras, the iron seems to have been principally used up by the biotite, whilst the rhombic pyroxene and the associated garnet too are almost colourless. The more basic rocks, approaching pyroxenites in composition, from Nagaramalai, in the Salem district, contain, on the other hand, highly-pleochroic hypersthenes with deep pink or even red garnets. Some of the rocks of the Nilgiris also contain deeply-coloured garnets associated with highly pleochroic rhombic pyroxenes that approach amblystegite in composition. As the pink colour of the garnets and the intense pleochroism of hypersthenes are dependent, though not in direct proportion of course, on the percentage of iron present, this simultaneous increase of intensity of colour would naturally be expected.

23. The facts cited under this head do not prove the *direction* of the chemical changes which have taken place amongst the rock-constituents, but as they indicate a constant chemical relation between the pyroxene and the garnet in the same rock, they are so far in agreement with the previously-stated evidence.

B.—MICROPEGMATITIC INTERGROWTHS OF GARNET WITH OTHER MINERALS.

24. The structure produced by the intergrowth of quartz and felspar in graphic granite has, since its first description on a microscopic scale by Zirkel in 1871, been known under such names as micropegmatitic (Michel-Lévy), granophyric (Rosenbusch) and implication-structure (Zirkel), whilst special types of it are known as ocellar structure (Fischer), centric structure (Becke), and pseudospherolithic structure (Rosenbusch).

Although the most common example of these structures is produced by the intergrowth of quartz and felspar, other minerals are found mutually entangled in a precisely similar manner.

25. Becke has mentioned cases of a micropegmatitic intergrowth of garnet and felspar in augite gneiss,[1] and Lacroix has described and figured a similar intergrowth of garnet and quartz in one of the pyroxenic rocks of Ceylon.[2] Heddle has mentioned the occurrence of quartz-inclusions in garnet giving apparently a similar structure.[3]

26. The commonest examples of the structure, namely, those produced by the intergrowth of quartz and felspar, have generally been considered to have originated during the primary consolidation of the rock by simultaneous crystallization of quartz and felspar in the proportions of an eutectic mixture.[4]

27. But in 1883 Irving suggested the secondary origin of the quartz in the micropegmatitic structures of some granites and augite-syenites near Lake Superior.[5] Professor Judd showed the secondary origin of the quartz in similar structures and associated with the felspars of some Mull and Portsoy gabbros.[6] In 1889 the same author produced further evidence in support of his original conclusion and showed the connection between these structures and the secondary growth of minerals in igneous rocks after their consolidation.[7] Further examples of the same structure, considered to be connected with the secondary silicification of rocks, have been described by Miss Raisin in some nodular felstones of the Lleyn in Wales,[8] and by myself in some rhyolites from Korea.[9]

28. The pyroxenic rocks of Chota Nagpore, in which I have just described the growth of garnets, afford most striking cases of micropegmatitic intergrowths of garnet with plagioclase, and less often with quartz, about the secondary origin of which there seems to me little room for doubt. These intergrowths are moreover, as in the examples mentioned by Professor Judd, directly dependent on the enlargement of the minerals after the primary consolidation of the rocks (Fig. 4).

29. It has already been mentioned that numerous small garnets are found springing up in the vicinity of larger masses, sometimes isolated and sometimes in clusters. Now, wherever patches of these small garnets are found the isolated crystals grow, as already described, with crystallographic parallelism to one another (para. 16). The bearing of this fact on the origin of the micropegmatitic structure is obvious; the growth from isolated centres continues until the crystals, already in parallel groupings, meet and join as one, whilst the felspar, formed as a by-product in the decomposition of the pyroxene and growing at irregular intervals, becomes enveloped in a continuous framework of garnet.

30. It has already been remarked, too, that the so-called reaction-borders appear only between the garnet and the ferromagnesian constituent undergoing change, whilst the former mineral shows a very definite and simple outline where it

[1] *Tschermak's min. und petr. Mitth.*, Vol. IV. (1882), p. 406.

[2] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 317, and *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 179.

[3] *Min. Mag.*, Vol. II (1878), p. 230.

[4] See Teall, Brit. Petrography (1888), p. 391.

[5] *U. S. Geol. Surv. Monograph* No. V, "The copper-bearing rocks of Lake Superior," p. 114.

[6] *Quart. Journ., Geol. Soc.*, Vol. XLII (1886), pp. 72 and 95.

[7] *Ibid.*, Vol. XLV (1889), p. 175.

[8] *Ibid.*, Vol. XLV (1889), p. 252.

[9] *Ibid.*, Vol. XLVII (1891), p. 177.

comes in contact with the felspar (para. 13). In this way growth occurs only opposite the ferromagnesian constituent, and the garnet bellies out in such areas, with the result that the bays and inlets are filled with felspar. A continuation of this process results in the complete envelopment of the felspar and its consequent appearance in section as isolated crystals. As might be expected, the crystal-outlines of the garnet are exhibited only when the pyroxene is sufficiently abundant to allow of free growth, whilst development is proportionately interrupted when such minerals as felspar and quartz are present in quantity. Both these processes are specially well illustrated in the garnetiferous rocks of Manbhúm and in the rocks of Parasnath.

31. Although a certain quantity of felspar and quartz occurs amongst the primary constituents of the Manbhúm and Parasnath rocks a larger quantity is formed as a by-product in the re-arrangement of the pyroxene-molecules. Hence it is that garnet is more frequently intergrown with felspar and quartz than with the more basic minerals. The minerals intergrown are thus produced simultaneously by secondary changes in a pyroxenic rock, and the average composition of the mixture of garnet and white mineral formed is approximately that of the original ferromagnesian silicate which has undergone the chemical re-arrangement of molecules.

V.—SUMMARY OF CONCLUSIONS.

32. The garnets occurring so abundantly in the pyroxenic rocks of India frequently exhibit fibrous reaction-borders generally composed of felspar, actinolite and sometimes magnetite, and display a radiate arrangement of the fibres similar to the structure characteristic of Schrauf's kelyphite.

33. The reaction-border occurs only between the garnet and a ferromagnesian silicate, never between garnet and felspar or quartz (para. 13).

34. The ferromagnesian silicate nearest the garnet is generally green actinolite which can be traced out in some cases (Manbhúm, Parasnath) to augite, and is evidently derived from the latter mineral by the ordinary process of amphibolization (para. 14).

35. The augite undergoing the paramorphic change into hornblende is darkened by the minute regularly-arranged inclusions which characterize diallage and present the ordinary phenomena of schillerization. The passage into hornblende is accompanied by the absorption of these dark ferruginous inclusions and clear green actinolite is the result (para. 15).

36. Where the rock is composed almost entirely of pyroxene changing to hornblende, the garnets develope with a regular crystalline outline, and several crystals developing in close proximity often exhibit crystallographic parallelism to one another. Where felspar and quartz occur in quantity as primary constituents, the garnet exhibits no crystal-outline, but is moulded on the white minerals, and the line of contact in such cases never shows a reaction-border (para. 16).

37. The garnets are frequently found bellying out opposite the pyroxenes, whilst felspar and quartz occupy the bays and inlets. A continuation of the growth of the garnet results in the gradual enclosure of such felspar and quartz crystals and their consequent appearance in section as isolated masses (para. 30).

38. The alteration of the original schillerized pyroxene is, therefore, not a simple paramorphic change, but is a decomposition which results in the simultaneous formation of a more basic mineral, garnet, and a more acid one, felspar.

39. The simultaneous development of these two minerals results in their micropegmatitic intergrowth. In the case of the felspar the similarity of optical orientation of isolated portions proves their crystallographic parallelism. In the case of the intergrown garnet the occurence of numerous small crystals developing around a larger central one exhibiting parallelism of crystal-outline with the larger central garnet and with one another, results in the ultimate formation of one large crystal of garnet, in which both original felspar and quartz, as well as the secondary felspar formed during the destruction of the pyroxene, become entangled to produce a micropegmatitic structure (paras. 29 and 31).

40. The micropegmatitic structure is thus considered to be of secondary origin as has recently been shown to be true for similar cases of the more common intergrowth of quartz and felspar.

41. The development of felspar as a by-product during the formation of garnet from pyroxene explains the more frequent record of micropegmatitic intergrowths of garnet with felspar than with any other mineral.

42. The reaction-border occurring around garnets may therefore represent a stage in the *development* of garnet from the products of the molecular disintegration of original ferromagnesian silicates, and does not always indicate the *destruction* of garnet as has generally been considered to be the case with kelyphite borders.

43. The evidence offered by the microscopic characters briefly indicated in the previous paragraphs is corroborated by the field relations of the pyroxenic and garnetiferous rocks. Compact pyroxenic rocks, with a perfect granitic structure, become friable and imperfectly foliated near their margins, where the pyroxene disappears, garnet, in about the same proportions, takes its place, and the rock becomes granulitic in structure (para. 19).

VI. EXPLANATION OF PLATE.

FIG. 1. Garnet crystal with reaction-border which only occurs between the garnet and the pyroxene, or, more strictly speaking, its paramorph hornblende. Along the bay, which is filled in with felspar, the outline of the garnet is a simple one without reaction-border. In this section the pyroxene, which is darkened by schillerization products, is amphibolized opposite the reaction-borders only, the portion abutting against the felspar being unaltered. In *pyroxene-diorite* from Parasnath, Bengal. Rock No. 9.-328. Slide No. 1154. Magnified by 43 diameters.

FIG. 2. Garnet crystals, large and small, developing in amphibole derived from pyroxene with crystallographic parallelism and showing reaction-borders. In *garnetiferous pyroxenite*, from the Ijri valley, Manbhum, Bengal. Rock No. 3·23. Slide No. 1376. Magnified by 25 diameters.

FIG. 3. Small garnets growing with crystallographic parallelism to a larger neighbour with reaction-borders. There are large numbers of such small crystals growing around the large one although beyond the limits of the field photographed. Slide No. 1976. Magnified by 43 diameters.

FIG. 4. Micropegmatitic intergrowth of garnet and felspar. The optical continuity of the isolated sections of the felspar is shown by parallel twin-bands when examined between crossed Nicols. Slide No. 1376. Magnified by 20 diameters.

Fig. 1.

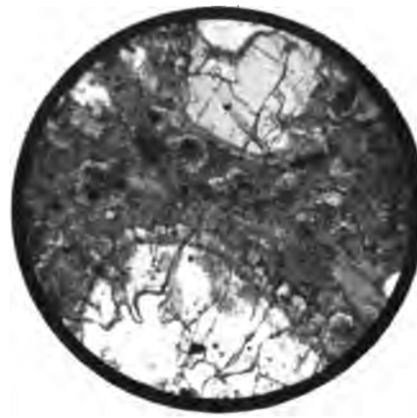


Fig. 2.

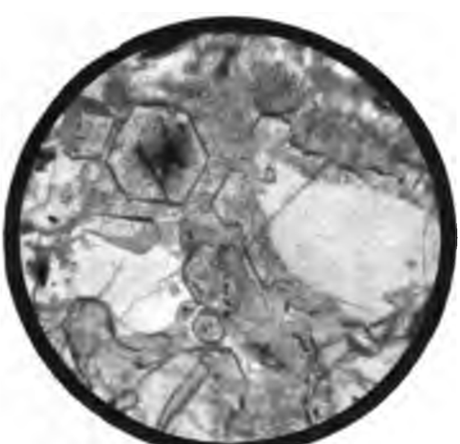


Fig. 3.

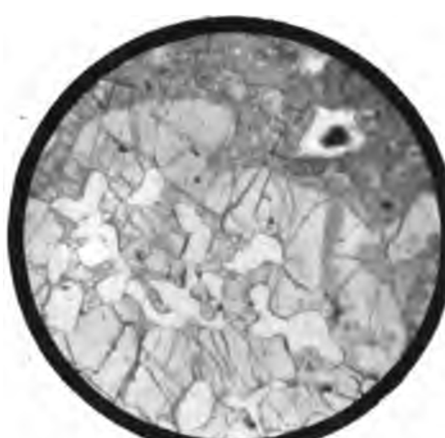


Fig. 4.

SECTIONS OF ROCKS, SHOWING THE GROWTH OF GARNETS.

Photographed by T. H. Holland.

Photo-etching. Survey of India Offices. Calcutta, February 1896.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1896. May.

Notes on the Ultra-basic rocks *and* derived minerals *of the* Chalk (magnesite) hills *and other localities near* Salem, Madras: *by* C. S. MIDDLEMISS, B.A., *Superintendent, Geological Survey of India* (with plates 2—6).

INTRODUCTION.

In substance, and with but slight alteration in form, these preliminary notes have already appeared in a report on the magnesite areas near Salem, prepared by me at the request of the Madras Government last year (1895). My investigations were, of course, chiefly directed to the magnesite, serpentine and chromite, from an economical stand-point; but I naturally gave some attention to the geological aspects under which they appeared, inasmuch as, from their comparative rarity rocks of the class from which such minerals are derived are always objects of interest to the geologist.

The following notes have reference to three separate localities, namely:—

(1) The two areas of the Chalk hills.
(2) That of the north-west end of Kanjamallai.
(3) That near Valaiyapatti in the Námakkal taluk.

Of these three areas the first is by far the most important. They will be taken for description in the above order.

(1) CHALK HILLS.

The two areas embraced under the above name have been described by Messrs. King and Foote in their Memoir (*Mem. G. S. of India*, vol. IV, pt. 2, 1864). The same areas were cursorily examined by Mr. Holland quite recently, and described (*Rec. G. S. of India*, vol. XXV, p. 135, 1892).

Whilst the two former observers gave a fairly detailed description of the mode of occurrence of the magnesite, with remarks on the accompanying minerals, Mr. Holland was able to come to more definite and accurate conclusions regarding the mode of origin of the magnesite, chromite, etc.—conclusions which have been abundantly confirmed and illustrated by my own visit.

In taking up work myself on these extremely interesting rocks, it was evident (considering that a generally descriptive account, and an up-to-date theory of them existed already) that any advance that I could make on the work of my

predecessors must be in the direction of greater precision as regards detailed surveying of the minerals and rocks of the area. My line of action was therefore clear, and the first step towards it was to obtain a detailed topographical map. This I found not to exist; and so, as the shortest way out of the difficulty, I set to work and planetabled the two magnesite areas of the Chalk hills myself on the scale of 6 inches to 1 mile, showing sketched contours of 10 feet. A reduction of the map, geologically coloured, accompanies this report (Plate 2.)

Position and area.

The Chalk hills lie a few miles north of Salem town. They comprise two areas. a smaller one to the south, through which at its south-west end the Madras Railway and the road to Omalur pass, and a larger one to the north-east of the latter, and which keeps a position to the east of the railway and road. The former contains about 1½ square miles and the latter (so far as shown in my map) about 3½ square miles. It extends, however, further away in a north-easterly direction.

Orography.

The hills rise gently from the plains, and expose a set of low undulating surfaces, generally bare of vegetation and without water. They are streaked with white, owing to the veins of magnesite (carbonate of magnesia) from which (erroneously) the name "Chalk" hills is taken.

General geological structure.

The structure of the two magnesite areas may be summarised as follows:—

(1) The plains surrounding the Chalk hills are composed of an ancient gneissic series, wrapped into folds with a N. E.—S. W. strike. These rocks form part of the great crystalline foundation of south India. They vary enormously in mineral composition at different places, but in the vicinity of the Chalk hills they usually have hornblende as the dark mineral. Their foliation is a marked characteristic: a foliation both fine and coarse, and rendered very apparent by the varying quantities of hornblende present in each layer. A hand-specimen may shew no hornblende at all, or a finely banded condition of it with felspar and quartz, or it may be composed entirely of hornblende. In certain places, as along the high ridge to the south of the north magnesite area, garnets of great size or in nests appear thickly distributed along the more hornblendic bands. Perhaps the greatest structural difference between these old gneisses and the presumably younger ultra-basic intrusions, which are the subject of this paper, is to be found in the greatly foliated condition of the former, and the total absence of any such in the latter. Indeed generally throughout South India, this distinction applies between the gneissic foundation and the intrusive rocks, whether ultra-basic, as here, basic as found in the great plexus of trap dykes that cut through the country, or acidic, as is found in the masses and veins of coarse granite which form considerable hills. In any and every case the younger intrusive rocks remain perfectly unfoliated and non-schistose from core to edge: they have no linear arrangement of their minerals, and no tendency to any uniform orientation of the long axes of those minerals.

(2) The two areas of the Chalk hills are essentially two such great intrusive masses of olivine-chromite rock, and other olivine-bearing rocks, which, from their containing little or no felspar or quartz, belong to the peridotite, or ultra-basic group of rocks, such as dunites, picrites, etc. These rocks, owing to the unstable mineral olivine, have undergone enormous mineral change, whereby, first the dunite became serpentinised more or less completely, and secondly, the serpentinised Product was further altered with the formation of magnesite, chalcedony, etc.

The evidence for the intrusive nature of these ultra-basic masses may be best seen along the south-west side of the north area, where the junction line with the old gneisses is distinctly seen to cut obliquely across the foliation of the latter. The age of these intrusive rocks remains at present undeterminable.

The Dunite and its contained mineral Chromite.

Mr. Holland was the first to detect the presence of dunite in the specimens which he collected in the Chalk hills and north-west of Kanjamallai hill. (See foot-note at page 144 of Mr. Holland's paper.)

This rock, first known from the Dun mountain, New Zealand, is composed entirely of olivine and chromite, and as such, in an unaltered condition, it is found at many places in the Chalk hills where the rock has resisted the metamorphic influences tending to convert it into serpentine. The top of "J" hill and of "Tent" hill, and the western end of the south area are examples of places where the rock of a grey or greenish-grey colour, may be observed. The grey rock (colourless in thin section), such as is found on the summit of "J" hill and near "KK" hill might be at first sight mistaken for a quartzite until the high specific gravity arouses suspicion.

The microscope shows the rock to be composed almost entirely of a coarsely crystalline aggregate of olivine, felted together, and with minute black crystalline grains of chromite dotted through it.

A chemical analysis of the "J" hill specimen No. 10·189, made in the Geological laboratory at Calcutta by Mr. Blyth, gave—

Silica	39·10
Magnesia	48·26
	87·36
Iron and alumina, Manganese, Chromium, Moisture, etc.	12·64
	100·00
Specific gravity	3·176

I give below, for comparison, an analysis of the dunite of the Dun mountain (Von Hochstetter)—

Silica	42·80
Magnesia	47·38
Ferrous oxide (after the chromite had been removed).	9·40

I next give that of oriental olivine, taken from Dana's Mineralogy—

Silica	39·73
Magnesia	50·13
Ferrous oxide	9·19
Specific gravity	3·351

There can be no doubt that originally nearly the whole of the Chalk hills area was composed of this extreme form of peridotite known as dunite. But mineral changes rapidly set in, and the two first of these changes that must be noticed are (*a*) the alteration, partially or wholly, of the olivine into serpentine, and (*b*) the segregation of the chromite into nodules and veins. With regard to the change of olivine into serpentine, I need say very little. It can be

followed most perfectly under the microscope by a series of transitional sections showing, first, a few veins of the latter anastomosing among and penetrating the crystals of olivine, afterwards breaking them up, then separating them into isolated small grains set like islands in a sea of serpentine, and which at last become very small and finally disappear. The subsequent changes which brought about the conversion of much of the serpentine into magnesite have effectually destroyed any ornamental qualities it might have possessed, by giving it a dull earthy appearance. Only here and there do there occur a few minute veins, a finger thick, of a pale apple-green serpentine, which might, if they had been on a larger scale, have been of economic use. Picrolite or fibrous serpentine, is also found in veins here and there.

Coming to the chromite, originally discovered by Mr. Heath, and worked by the Porto Novo Company, the only observations we have as to its mode of occurrence are those made a long time ago by Newbold, and those of recent date by Holland. The former found the mineral in very thin veins, either lying among the magnesite of the veins or between it and the walls of the veins. The observations were drawn from an examination of the mines near the chimney on the accompanying map (Plate 2). Holland corroborated Newbold's observations in this respect—see *Journal, Roy. Asiatic Soc.*, vol. VII, 1843, pp. 167—171. Of the three shafts marked on my map the middle one is the largest, and though I explored this carefully, I could find no trace of the mineral left in the crumbling rock-walls of the shaft.

In some small pits sunk along the position of the line marked chromite vein on the map (some of which appear to have been enlarged lately), I was able to see the position of several veins of the chromite. Three vertical parallel veins a quarter of an inch, 1 inch, and ½ inch wide respectively, and separated by a few inches of serpentinised matrix, occur striking E. 20° N. at a position on the map N.W. 5° N, from the chimney, and distant about 650 yards (see pl. 5, fig. 1). Nearly horizontal magnesite veins may be seen interrupting and cutting across both the matrix and the chromite veins. In one place a vein of magnesite has not only interrupted, but also displaced, the middle vein of chromite, showing that the magnesite was, in this case, the last to form.

What is undoubtedly a continuation of the same vein towards the E. 20° N. is to be seen at several points between 900 and 1,000 yards off. At no other places in this north area was chromite found *in situ*.

It will be seen from the map, however, that in this area a little east of the chimney there is a space of country from which six stream-beds radiate in different directions. In every one of these stream beds, and especially in their higher parts, chromite, in lumps, varying from one foot to one inch or even less across, may be picked up (the places where such have been found are indicated on the map by dots).

It is clear, therefore, that the area drained by these streams is penetrated by chromite veins. Unfortunately my data are too scanty for any attempt to estimate the amount of chromite available to the miner; nothing but a practical test within the area of, say, 1,000 yards radius from the chimney would settle this all-important question. Geology has gone as far as it can, unaided, in the matter.

In the southern area of the Chalk hills the map similarly shows, by means of

dots, the places where chromite has been picked up at the surface. No chromite, actually *in situ*, is known in this area; but the indications of it in the stream between "Tent" hill and "Green bush" hill, and in the one to the south-west of "Tent" hill, show that the centre of this area is approximately the true location of the chromite. No mines have been worked in the area, but I have no doubt that if extensive quarrying of the magnesite is ever carried out, chromite veins will in due course be laid bare.

As for the quality of the ore, the nodules and lumps as picked up among the hills show that it is practically a granular-crystalline aggregate of the pure mineral, chromate of iron, the theoretical composition of which, as given by Dana, is—

Chromium sesquioxide	68·0
Iron protoxide	32·0
	100·0

but chromite varies much in the amount of the sesquioxide present, 50 per cent. being considered a very good quality of ore.

The actual analysis of the ore, as found in the north area of the Chalk hills, is given in Newbold's paper referred to above. It was made by Mr. E. Solly, and gave—

Chromium sesquioxide . . .	49·00 per cent.
Which is about equivalent to chromic acid	57·00 „
Or to cent. per cent. of chromate of potash.	

The following description of the method of working and transporting the ore to the coast is taken from Newbold's report:—

"The ore is separated from the rock by means of pickaxes, chisels, wedges, and hammers; "sorted and piled up into little heaps on the ground in front of the huts occupied by the "superintendents, where it remains until the Cauvery becomes navigable; that is, from the "end of June till the end of September. It is then sent down by land to Moganoor, a place "on the river about 40 miles southerly from Salem, whence it is boated to Porto Novo on the "Coromandel coast. Thence it is shipped to Europe by the Porto Novo Iron Company."

About 100 tons are said to have been extracted from the mines, one block of which weighed two tons, but it was found that the export of the crude ore to England did not pay owing to the quantities available from Scotland, Styria, etc. At a depth of 50 or 60 feet from the surface water was met with, and it is not impossible that it was this difficulty which helped largely to stop the work, inasmuch as no better means of removing the water were used than buckets and ropes.

Other ultra-basic and basic rocks of the Chalk hills.

Besides the dunite, and its more immediately derived serpentine and chromite-veins, there occur, somewhat sparingly, examples of other less basic rocks. They are generally black or of dark colour, and stand out in rounded lumps, having escaped the great alteration which the dunite has suffered. They are represented on the map by a purple colour. Many of these in the north area are situated round the margins of the dunite intrusion. One remarkable one is found to the east of "Green bush" hill in the south area. The latter No. $\frac{10}{191}$ is a very coarse aggregation of diopside, olivine and biotite. The first two minerals are in a granular-crystalline state, whilst the biotite fills in the interspaces. Apparently genetically related to the preceding specimen is $\frac{10}{198}$ from the cart track N.N.E. of knoll "C." It also

contains diopside and olivine in more or less idiomorphic crystalline granules; there is a small amount of biotite; and all these minerals are set in a groundmass of small felspar crystals. The diopside is schillerized in a remarkable way. Similar rocks are found in the stream-bed S.S.W. of K, *e. g.*, $\frac{10}{197}$.

The Magnesite veins.

I come now to the mineral which is most abundantly represented in the Chalk hills, that is, the magnesite, or carbonate of magnesia. Its general characteristics, mode of occurrence, and appearance have been described by many observers, among whom may be mentioned Newbold (*Journal, Roy. Asiatic Soc.*, vol. VII, page 161, 1842), King and Foote in their memoir cited above, and lastly Holland. The descriptions of the earlier observers stand good at the present day, if we simply substitute the more correct mineralogical descriptions of the rocks from which it was originally derived in the place of the hornblende-schists, micaceous and massive talcose schists, basalts, etc., of these observers. The mistake made by them (perfectly intelligible before the microscope was regularly employed for the examination of rocks by means of thin sections) was of a simple nature. They looked upon the area of the Chalk hills as primarily a focus of metamorphism, brought about by a locally intense extravasation of hot acid waters or vapours, which were sufficient to change the otherwise stable minerals in the gneissic rocks surrounding the area. Mr. Holland's and my own researches, on the other hand, have simplified the matter considerably by the discovery that the rock forming the groundwork of the Chalk hills areas is entirely different from the surrounding gneissic rocks; that it is in fact, as has been described above, a nearly pure olivine rock in various stages of alteration. The fact of such an olivine rock having at one time been erupted into the older gneisses in this part of the country is in itself sufficient to account for the secondary masses of serpentine and veins of magnesite, without having recourse to hot acid waters emerging at particular places; inasmuch as it is the nature of olivine rocks to rapidly undergo changes into serpentine and magnesite. The mineral is of such an unstable nature as to readily lend itself to these changes under normal subterranean or surface conditions (without calling into play any special metamorphosing agents), whilst the ordinary gneisses of the country, and the less basic rocks surrounding the area, remained practically unaltered.

I need say very little, therefore, as to the general occurrence of the magnesite here, except that it appears in veins, which although they have, in places, a tendency to a particular alignment along what were probably originally joint planes in the dunite, are nevertheless as a rule completely irregular in their disposition. The number of veins, and the corresponding quantity of the magnesite, were points to which I particularly directed my attention; and which I have endeavoured to represent on the accompanying map. The uncoloured part of the map where topographical detail is given embraces the whole area where the dunite is found and stands for that in which the magnesite is least in evidence or absent altogether. The cross-shaded portion is that in which there is a fair amount of the magnesite; whilst the deep-blue wash represents the parts richest in magnesite. I have been compelled for diagrammatic purposes to draw the boundaries of the different areas as sharp, but I need scarcely remark that in nature there are no such hard and fast lines; the richer and the poorer rock grading into each other.

(1) The richest areas (coloured blue) are, generally speaking, the western end of the north area, and the south side of the south area. I estimate that the proportion, by volume, of the magnesite in the rock in these richest parts is about one-half or one-third of the whole rock.

(2) The moderately rich area (cross-shaded) occupies generally the more central parts of the Chalk hills; and I estimate that the proportion, by volume, of magnesite here is only from one-sixth to one-tenth, or even less, of the whole rock.

(3) The poorest area (uncoloured) merely shows a few thin veins and patches of the magnesite here and there, and impossible of estimation.

The total area embraced under heading No. (1) above, in the two parts of the Chalk hills taken together, amounts to about 620,000 square yards, that under heading No. (2) amounts to about 5,536,000 square yards.

Considered altogether, the amount of magnesite in these hills is practically unlimited. The richest portions (as visible at the surface) stand up in rough lumpy hillocks, sometimes, as in the case of the hills at the western end of the north area, rising as much as 100 to 140 feet above the plains, whilst in other parts, as the south edge of the south area, they rise only to 30, 40, or 60 feet above the plains. Hence the mineral (if any demand for it ever does arise) can be worked in open quarries and taken away to the rail. The quarries could all be reached by a light tramway, or by carts.

Two outline views of the two areas are appended to this report to show the configuration of the country (Plate 6), and two photographs to illustrate the surface appearance of the magnesite veins (Plates 3 and 4).

(2) KANJAMALLAI AREA.

Mr. Holland (*Rec. G. S. of India*, vol. XXV, p. 142) was the first, I believe, to draw attention to the presence of ultrabasic rocks and magnesite in small amount at the north-west end of the Kanjamallai hill in a depression at the head of a little stream running down to Sithaswaran kovil (temple). Therein also he remarks on the possibility of finding chromite associated with the magnesite.

On visiting this part myself last season, I found the rocks as described by Mr. Holland. But the amount of the purer olivine-chromite, ultra-basic, intrusive rock (dunite) as found at the surface was, however, extremely small. It is of a pale greenish-yellow colour and crumbles easily. Veins of magnesite run through it. In close relation with it was a brilliant dark-green rock composed of enstatite and a bright-green pyroxene (diopside), a rock which is also found in the extreme north-east parts of the north magnesite area of the Chalk hills, on the east side of the double-peaked Nagramallai hill (not represented on the map).

Mr. Holland's prediction as to the possible finding of chromite here was verified by my coming upon a band of it about 4 inches thick among the magnesite and decomposed ultra-basic rock. It was only exposed for the short distance of about 3 yards.

The whole exposed area of these rocks in this locality is in length not more than ¾ mile and in breadth ½ mile. It appears to follow round the eastern end of the depression at the north-west end of Kanjamallai in the angle formed by the main ridge and low continuation of it south of Sithaswaran kovil (temple). I could not find any trace of it anywhere else on the Kanjamallai ridge.

To the south of Kanjamallai hill, and running parallel to, and north of, the Salem-Sankaridrug road, there is a little row of hills composed chiefly of talcose schists and dunite, with a mere trace of magnesite among them. The talcose rock was locally worked as pot-stone for making rude vessels (feeding troughs for cattle, etc.).

Both these two areas are too small to be considered as of any importance from the magnesite they contain; but the chromite of the former, and the pot-stone of the latter, may be considered as of some economic value. The chromite is in close proximity to a thick bed of magnetite.

This paper does not profess to deal with the iron ores of Kanjamallai, but I may mention that a few average specimens from the lowest and thickest band of magnetite schist at the south foot of Kanjamallai were analysed in the Geological laboratory by Mr. Blyth and gave :—

No. 10·212 (a fine-grained, almost aphanitic rock, a large specimen of which I sent to the Madras Museum).—

Specific gravity	3·365
Per cent. of iron	35·00

No. 10·243—

Specific gravity	3·531
Per cent. of iron	34·390

No. 10·239 (a coarsely crystalline quartz-magnetite rock) :—

Specific gravity	3·538
Per cent. of iron	36·66

(3) THE VALAIYPATTI AREA.

This locality is one of those described by King and Foote in their memoir cited above, p. 96. The amount of magnesite present is extremely small. The ultrabasic rocks which have given rise to the magnesite are the same as those last described from north-west end of Kanjamallai, but I did not find any of the pure olivine rock analogous to the dunite of Chalk hills.

The actual locality is a little south (from half to one mile) of Palappatti of the one-inch map of the Namakkal taluk (Madras Survey). The magnesite is exposed over an area of one mile by half a mile, and it is developed among rocks which contain a considerable quantity of enstatite, with green pyroxene (diopside).

Besides this particular area there is actually at Valaiyapatti, another occurrence of similar rocks, which stretch away in a long narrow band east and west of the town. They form little hills rising sometimes steeply, and forming a discontinuous chain. With them east of the town occurs a rock of an extremely acid type, a very coarse red or pink and white pegmatoid rock or graphic granite, composed of quartz and felspar, which have crystallised together simultaneously.

These are all the localities with magnesite that I have so far visited. The first is the only one in which the mineral is developed in sufficient force to be of any practical use.

Preliminary notes[1] *on some* Corundum localities *in the* Salem and Coimbatore districts, Madras: by C. S. MIDDLEMISS, B.A., *Geological Survey of India.* (With plates 7, 8 and 9.)

I.—INTRODUCTION.

In these notes I shall merely endeavour to give a concise account of such facts as to the distribution and occurrence of corundum in the districts referred to under the above heading, as have up to the present been investigated by me. All discussion of theoretical questions arising from them, except in so far as such questions bear on the distribution of the mineral, will be left for a future more complete report, when these investigations have been brought to a close.

A few remarks of a general nature have already been made by me in my progress report for the working season 1893-94, and reproduced in substance in the annual report of the Geological Survey for the year 1894 (*Rec. G. S. of India,* vol. XXVIII, pt. 1, p. 3). I need not do more here than refer to them, as all important details contained therein will be embodied in the present report.

Corundum localities visited by me.

A list of corundum localities, as represented by specimens in the Madras Museum, was kindly furnished me by Dr. Warth (then officiating as Superintendent of the Museum) on my arrival in Madras. Of those the following is a list of the localities where corundum has been examined by me :—

(1) Sithampundi or Sittampundi, near Solasiramani (Sholasigamani) Námakkal taluk, Salem district.
(2) Paparapatti and neighbourhood, Dharmapuri taluk, Salem district.
(3) Rengopuram, Dharmapuri taluk, Salem district.
(4) Road from Dharmapuri to Morappur.
(5) Selangapalaiyam, Bhavâni taluk, Coimbatore district.
(6) Gopichettipalaiyam, Coimbatore district.
(7) Karutapalaiyam, Coimbatore district.

The following localities, though they have been quoted as corundum localities, have proved not to contain corundum in some cases, or else local information on the subject was found to be wanting :—

(8) Yellagiri hills, near Jalarpet.
(9) Neringipet, Coimbatore district.
(10) Chinnamallai, Coimbatore district.
(11) Kanjikovil, Coimbatore district.

With regard to the Yellagiri hills, I was in the first place unable to obtain any information from the local officials of Tirupatur, as to the occurrence of any corundum there. On visiting the hills themselves, and making enquiries both in the villages at the foot and on the summit of the plateau, I was similarly unable to elicit any information on the subject. A necessarily somewhat hurried personal investigation of the geology of the hills was also without success. I found the hills to be composed of a great intrusive mass of a rather medium-grained granite,

[1] With few slight alterations these notes are a reprint of a report written for, and published by, the Madras Government, 1895.

slightly pinkish in colour, but sometimes white and sometimes deep flesh-colour. Here and there on slabs of the rock exposed along the rolling, plateau-like summit were to be seen large, porphyritic crystals of felspar which at once catch the eye in the sunlight. It may possibly be the case that these crystals have been mistaken for corundum.

Neringipet I have not as yet visited, but the Bhavani Tahsildar informed me that the reported find there was a mistake.

Chinnamallai is a long, low hill-range of ironstone (magnetite-schist, etc.) among gneisses. I could find no one in the neighbourhood who knew anything about corundum occurring in the neighbourhood, nor was I successful in discovering any trace of it myself.

At Kanjikovil, I was directed by the Bhaváni Sheristadar to a number of shallow pits situated about 2½ miles along the Satyamangalam road from Sittodu. Here I found a quantity of grey and blueish grey kyanite crystals scattered through the rock, in the soil, and in the debris thrown out of the pits. It is possible that this mineral was mistaken for corundum; and it is even possible that similar finds of blueish varieties gave rise to the report mentioned by Newbold (see on) that sapphires have been found in the valley of the Cauvery. [1]

II. DESCRIPTIONS OF THE LOCALITIES.

(1) *Sittampundi area.*

This locality lies a little east of the Cauvery river, and about five miles to the south of the boundary dividing the Tiruchengódu taluk from the Námakkal taluk. It has apparently been known for a very long time. Specimens of corundum and of the enclosing rock from it were described by Count de Bournon (*Phil. Trans. Roy. Socy.*, 1802, p. 282), and the place was visited by Captain Newbold and reported on by him (*Journal, Roy. Asiatic Socy.*, vol. VII, p. 224). Lastly Dr. Warth of the Geological Survey visited and reported on it in two letters to the Madras Government, Nos. 540 and 606, dated 24th June and 16th July 1892, respectively.

Area.

The size of the area productive in corundum was given by Dr. Warth as 771 acres, but the village officers gave 1,000 acres as the estimated amount. It was also stated to be about four miles long and two miles broad in its widest part.

The part examined by me was about two miles long and varied in width from 100 yards to 1,000 yards. It lies south-west, south, and south-east of Sittampundi village, occupying a slightly elevated bit of rising ground running with its long axis west-north-west, and east-south-east at distances varying, according to the position, of from 1 mile to ½ mile from the village.

It was in December 1893 that I began my corundum investigations in the district at this place, first on account of its being the one about which most information was obtainable. The following summary is based on the observations then made in the field, and on the subsequent examination of the rocks and minerals in the laboratory.

[1] In view, however, of the discovery by Dr. Warth of blue corundum in a vein of kyanite in Chota Nagpur this place may be worth while visiting again (see *Records*, vol. XXIX, p. 50).

Rocks of the neighbourhood.

The rocks to the north of the corundum area consist generally of a great series of biotite gneissic rocks, covering large areas, and with bosses and veins of a coarse, reddish granite bursting through them and often forming picturesque crags and precipitous hills, such as that at Tiruchengodu town, and the similar hills in the vicinity.

Actual matrix of the corundum.

But the actual rock present at the corundum workings differs from the above in being a gneiss or gneissic rock, of a pale silvery or pearly grey colour, streaked with black, and consisting of anorthite (indianite) and hornblende, chiefly, with accessory minerals garnet, and minute quantities of chondrodite (?). In structure the rock is a crystalline granular aggregate of anorthite, with rather elongated prisms of hornblende, sparsely or numerously arranged with their long axes roughly parallel to the foliation.

The rock is well foliated in bands which generally run perfectly straight, and which differ in the relative amounts of the pale mineral (anorthite) and of the dark mineral (hornblende) present. (See Plate 7, fig. 1.)

In some places the hornblende, in others the anorthite, make up nearly the whole rock. Garnets also become locally very numerous. The specific gravity of a specimen with but little hornblende and garnet was found to be 2·824. In this respect it closely resembles anorthite, the specific gravity being a little higher than that of the latter on account of the hornblende.

It is among this gneiss that the corundum appears, dotted about at random among it like porphyritic crystals of orthoclase in a granite. The mineralogical composition, structure, and general appearance of the rock-matrix here is plainly the same as that recorded by Count de Bournon from the Salem district, and named "Indianite" by him. The microscopical examination of the two rocks shows them to be practically identical.

Other minerals associated with the gneiss.

In some sort of association with the anorthite-gneiss, which is not disclosed by any exposures on the ground, there must occur a very coarse binary granite consisting of quartz and pink or flesh-coloured orthoclase-felspar, inasmuch as large pieces of the latter, and beautifully clear, smaller fragments of the former are found scattered over the ground in perfectly fresh lumps and showing no trace of rolling by the action of water.

On each side of the *in situ* gneiss, which forms the rising ground, there are gentle slopes of the same rocks, partly or wholly buried under surface material formed of the broken-up gneiss and with here and there a recent calcareous pisolitic tufa, derived no doubt from the decomposition of the lime-felspar (anorthite).

The corundum of the area.

The corundum occurs in two ways in the area:—

(1) In the bed-rocks as described above.
(2) In the gentle slope of debris along with the weathered pieces of the bed-rock.

It is of a pale greenish-gray, rarely flesh colour, and occurs sparsely distributed among the parts of the gneiss which are richer in anorthite. It takes the form of irregular lumps averaging from one-fourth to one inch in diameter. They do not, as a rule, show the prismatic and pyramidal faces, though some specimens

from this locality in the Survey Museum are in the form of short six-sided prisms characteristic of corundum. They exhibit, however, rhombohedral cleavage, which may be detected as fine and very regular lines crossing one another at an angle of about 95 degrees, and ruled as it were at fairly regular intervals. These fine lines crossing one another in this distinct way are a good practical distinction in the field between this mineral and pieces of orthoclase, or other felspar, especially in the case of the flesh-coloured corundum, which at first sight may be easily confounded with the flesh-coloured felspar referred to in the previous paragraph. It is possible that some of the lines may indicate repeated twinning, but the difficulty of cutting microscopic sections or of getting sufficiently thin cleavage flakes of the mineral, make it at present impossible to decide this point.

Nearly all these pieces of the mineral are surrounded by a shell of calcite from one-fourth to one-eighth inch thick, in which they lie among the matrix. This shell appears to be left by the crystallising out of the alumina (corundum) from the lime-bearing felspar (anorthite).

The corundum found in the debris slopes is the same as that of the matrix rock, inasmuch as the former is simply derived from the latter by weathering.

Red corundum or ruby of the area.

Besides the grey corundum noted above, and the flesh-coloured variety into which it passes, there are to be found fragments, generally minute, of red corundum, which very locally pass into ruby. The brighter coloured pieces of these, which are but seldom larger than one-fourth of an inch in diameter, were found by me only in the more hornblendic layers of the gneiss; and they lie in it surrounded by a shell of anorthite partly converted into calcite. These pieces are not generally transparent, but dull and opaque, and of a red-currant colour. But here and there minute points of a fairly translucent red colour may be detected, and I have no doubt that occasionally rubies of value have been extracted from these rocks, as is reported traditionally and by Newbold (*Journal, Roy. Asiatic Socy.*, vol. VII, p. 224).

Old corundum workings.

The grey and the flesh-coloured corundum are found all over the area to the south-west, south, and south-east of Sittampundi, referred to in page 40. The native workers have in some cases taken the trouble to break up the rock-matrix along the more rocky parts of the rising ground, and so to extract the mineral from its shell of carbonate of lime. But more generally it has been gathered by merely grubbing among the debris between the *in situ* outcrops and along the slopes. Shallow excavations of this sort a foot or two deep are to be met with all over the area. Women chiefly, but men also, take part in the search, which they conduct with the help of a small digging implement and a basket. The searchers pick about among the talus until they find traces of corundum. They then set to work to dig out a basketful of the material which is then gone over by hand, the fragments of corundum being selected readily and with certainty by those accustomed to the work.

I was informed that the grey corundum was sold locally at the rate of eight seers for the rupee, and that a man can collect that much in about fifteen days. The red corundum with occasional clear ruby particles is more locally distributed and I only know of one set of small workings and pits at a point one and a half miles south-east by east of Sittampundi and S. 8° E. of Anagherry

hill. There are several openings along one line of strike running north-west by west and extending for about 100 yards, but most of them have since been filled up by the falling-in of the sides. One mine was about fifteen feet deep, cut out along the strike, and from two to three feet wide. It had been much deeper (several yards I was told) but had subsquently been partly filled in with rubbish from above. Two years ago, I was told, this mine was worked, and the red corundum sold in Tiruchengodu for 1, 2, 3 and 4 rupees, according to the colour, transparency, and size of the pieces. Figure 2, plate 7, is a rough sketch-section of the mine.

Emery.

A piece of emery was picked up by me at the surface of the ground south-west of Sittampundi, but the rock was not found *in situ* any where.

Uses of corundum.

There seems to be no doubt about the practical uses to which corundum can be put as an abrading and polishing agent by armourers and lapidaries in the country. Mr. Ball surmises (Manual of the Geol. of India, pt. III), that the consumption of corundum in India must be considerable, though possibly it was larger formerly than now, as the trade of the armourer is possibly not so active now as it used to be.

Quantity of corundum available.

It is not possible without making some careful test experiments on a fairly large scale to say how much corundum, relative to the matrix, there is present. I was only able to make a few experiments with a few coolies in collecting the mineral from the surface from which an average of about ½lb. for one coolie working one day can be deduced.

Mining on a large scale.

If mining on a large scale in the bed-rock be ever undertaken and found profitable, we might expect a gradual extension of the productive area by the laying bare of rocks along the same strike, and by enlarging the present area of solid rock exposed after the surface debris has been cleared away. Hence my remarks in my letter to the Government of Madras of 25th October 1894, recommending that all facilities should be given to the leasing of the mines, so that their productiveness may be tested and data be obtained for future guidance. Inasmuch as the ordinary corundum occurs distributed in the bed-rock in the manner I have indicated, and not in veins or lodes in small and restricted places, there is no probability that the mineral will suffer a rapid exhaustion; because it is certain that the part now visible above the alluvium is only a fraction of what lies hidden beneath it.

(2) *Paparapatti area.*

Paparapatti lies ten miles north-west of Dharmapuri town. In a direct line one and a half miles away to the west-north-west is a range of rugged hills, and between the two there stretches an alluvial plain with rock out-cropping here and there. Most of this plain is taken up with cultivation. The corundum is widely distributed over the area. As an indication of what is already known of its distribution, I have traced an outline map from the one inch Survey map and marked with crosses the places where corundum has been actually seen and found by me (Plate 9). It does not follow that this represents the limit of this corundum locality, but no information as to the extension of the areas could be obtained at the

time of my visit, which was cut somewhat short by a pressing demand from the Madras Government to visit the magnesite area of the Chalk hills near Salem.

Nature of the neighbouring rock.

As in the Sittampundi area the surrounding rocks of this neighbourhood are gneisses, or gnessic rocks, with biotite as the dark mineral present. They are well foliated, with a foliation-strike approximately N. N. E.—W. S. W., that is to say, agreeing with the general trend of the hill range to the west of Paparapatti. At the actual corundum localities there is, however, no appearance of a hornblende-anorthite rock such as is the matrix at Sittampundi. The rock, a biotite-gneiss, still continues the same in character over the whole area, with the exception of a very local change, to be alluded to presently. Veins of a very coarse granite with red felspar and clear white quartz penetrate the gneiss, as well as veins of a closer-textured purplish granite. There are other intrusive veins of dark compact trap.

The matrix of the corundum.

The actual matrix of the corundum in this area is apparently an altered form of the biotite-gneiss. Elliptical (in section) or lenticular portions of the gneiss appear to have had their minerals re-arranged and altered; the dark mineral biotite segregates into an outer layer surrounding the lenticular portion, whilst the central parts of it remain more purely formed of deep flesh-coloured orthoclase (finely crystalline, and showing under the microscope a fine micro-perthitic intergrowth of possibly plagioclase) the amount of which varies with the amount of corundum present. Along with this changed appearance of the gneiss the foliation of the rock in these lenticular patches becomes much less pronounced and occasionally disappears altogether.

The size of these patches is sometimes as much as 3 or 4 feet long by six inches or a foot across where actually seen in the rock; but that they are in some parts much larger is shown by the huge lumps of the changed rock found lying on the hill-side.

On the hill-sides W. N. W. of Paparapatti the *in situ* gneiss containing these presumably altered lenticles, with corundum developed additionally, may be seen but rarely. Even then the hill-side is so completely broken up and weathered into loose, tumbled blocks that it is quite impossible to get any approach to a natural section showing the true relation between the areas of altered and unaltered rock.

The corundum itself.

The corundum here differs entirely in appearance from that of Sittampundi. It is of a deep purplish-brown or sometimes dark greenish-grey colour, and it is always regularly crystallised into hexagonal prisms with a great number of variously inclined pyramidal faces imperfectly developed, and so giving the prism an elongated barrel, or even spindle shape (see plate 7, fig. 3). These elongated prisms lie towards the central parts of the lenticular patches of changed gneiss last described, arranged in any direction, but generally with a tendency to an imperfect parallelism of their long axes with the long direction of the lenticle, which itself again is roughly parallel to the foliation of the surrounding gneiss.

The size of the corundum crystals, cleavage, etc.

In size they vary from extremely minute grains and crystals, only visible in a microscopic section, to large crystals, several inches long and from ½ to 1 inch in diameter. The characteristic, rhombohedral cleavage is easily made manifest by breaking

the crystals and sometimes as in the crystal figured (fig. 3) traces of the cleavage planes are visible on the prism faces. Occasionally also a combination of the rhombohedron and prism may be seen in a single crystal.

Shell of orthoclase round the corundum.

Besides the generally altered rock in which the corundum is embedded, each crystal is immediately surrounded by a shell of more compact orthoclase, generally flesh-coloured but sometimes white, having a thickness of from $\frac{1}{4}$ to $\frac{1}{8}$ inch. When a corundum crystal has been broken out or has dropped out from the rock, the place where it lay can always be distinctly recognised by this shell which remains behind.

Arrangement of the corundum-bearing rock in lines.

It is clear from the map that the outcrops of the rock in which corundum occurs lie in successive lines, roughly parallel to the strike of the gneiss, namely, N. N. E.—S. S. W. This seems to show that the particular bed, or band, of the gneiss fruitful in corundum, is repeated by the foldings of the rocks, so that it appears several times at the surface. Should this tentative conclusion be correct, it has a practical bearing on the amount of corundum in the locality, because it makes it very probable that the lines of fruitful rock which have continued as far as shown on the map will also continue further in the same direction in either continuous or broken outcrop.

Native ways of obtaining the mineral.

There are two ways of getting the mineral here corresponding to the case of Sittampundi, *viz.*, (1) by working the bed-rock and (2) by digging in the talus of débris at the foot of the hills and slopes. No extensive working of the bed-rock has been practised; but the richer lumps have been broken up, when not too hard or too large for demolition by hand. Numerous shallow pits in the débris and half-decomposed rock have been made. In general, it may be said that the mineral is gathered in an unsystematic, casual way, not as a regular pursuit, but only during the hot weather or at times when the soil from an agricultural point of view requires no attention; also during times of scarcity. A good deal is also gathered at ploughing times and at any time, especially after rain, by being picked up when met with without special search. By these means at certain times the mineral is accumulated and sold in the market as a regular article of commerce. Merchants from Madras and Bombay, it is said, buy large quantities of it at intervals when the local collections have accumulated.

Working on a large scale systematically.

As in the case of Sittampundi, it is impossible to say whether working the mineral systematically would pay. Such a question can only be decided by actual experiment carried on in such a way that the correct average percentage of corundum obtainable from a given amount of rock may be deduced. Towards the south-west of the corundum-bearing area there is a stream of water which is said to be perennial. This could be turned to account in sifting the more finely distributed particles of corundum in the matrix after breaking up and gentle pounding. These minute grains at present over-looked are as valuable as, or possibly more so, than the larger fragments, volume for volume; inasmuch as the corundum must first be reduced to the granular form before it can be used as an abrading agent.

Conclusion.

On the whole this area near Paparapatti is a decidedly promising one. The amount of corundum present in the rock appears to be sometimes considerable, and the area of known outcrops is a large one.

(3) *Rengopuram.*

Locality limited.

So far as I know personally, and also by report, this locality is an isolated and limited one. At the same time it should be remembered that negative evidence goes for very little in such a matter as the recognizing of small pieces of corundum, and especially in uncultivated forest land, where the soil is never disturbed.

The actual place of the corundum is two miles N. by E. of Rengopuram, a village on the outskirts of the forest land near Penagaram.

Two pits.

Here are to be seen two pits a few yards apart. The newer of the two is about 15 feet long by 8 feet broad, and 5—8 feet deep, and is sunk through a rock composed of alternate layers of a felspathic rock and a hornblende gneiss. I could find no corundum in the rock itself although I made a careful and prolonged search. The villagers and servants with me were equally unsuccessful. The mineral was, however, abundant in the surface débris overlying the edges of the mine. It is possible that this surface material may have come from a more distant point by a movement of soil-cap down the slope. The difficulty was to account for the mine which had been carried down some distance into the bed-rock.

The corundum colour, form, etc.

The corundum here is of a greenish grey colour and is very much rounded and waterworn into holes, and even slightly honey-combed (facts supporting the belief that it came from some distance). Hexagonal short prisms were the prevailing forms which it assumed, and most of these showed a tendency to break up parallel to the basal plane, thus forming irregular plates. There is no good basal cleavage, however, the rhombohedral cleavage being the only noticeable one.

(4) *Road from Dharmapuri to Morappur near 6th milestone.*

The first of the two localities embraced under the above heading lies one mile south of the 6th milestone from Dharmapuri, at the foot of a low hill a little west of the foot-path. The nature of the rock, and the mode of occurrence of the corundum resemble entirely those of the Paparapatti area. The exposure shows signs of having been worked within a radius of a few yards. I could not find, or hear of any other exposures of the same rock in the neighbourhood. The low hill range west of the Mukkunur range and that range itself are petrologically of different constitution. Here as before, however, negative evidence counts for very little. A band of the corundum-bearing rock may continue from this outcrop though hidden from view at present.

The other locatity is two miles north of the same milestone. There is no good exposure of the rock. A few fragments in a field alone reveal a few bits of corundum of a dark grey colour set in a very fine-grained, fissile rock almost resembling a phyllite or schist.

(5) *Selangapalaiyam.*

Locality.

The first locality I visited in Coimbatore district was the above. The corundum occurs scattered in fragments and rolled pieces in a field extending from near Chinnanayakkanur to Selangapalaiyam.

Nature of the enclosing rock.

The solid rock of the neighbourhood is very imperfectly seen. There are no rocky masses and no quarries. So far as one can gather from fragmentary observations, the rock of the country here is a muscovite-biotite gneiss, with wavy foliation, and with veins of a coarse binary pinkish graphic granite penetrating it irregularly.

The corundum, and mode of gathering.

The fragments of corundum are of a pale greyish green colour, sometimes brown outside. It has no crystalline form, but is in irregular lumps varying in size from $\frac{1}{2}$ inch to 1 and 2 inches across. Nearly all are rolled, but the rhombohedral cleavage is generally distinguishable.

The village karnam of Selangapalaiyam informed me that it was not gathered systematically, but picked up from the fields chiefly by women, during the rains. Perhaps 25 or 30 maunds were gathered annually.

(6) *Gopichettipalaiyam.*

Locality.

This is a limited locality like the last and is simply a field, from the surface of which the mineral is gathered. The village magistrate owns the field, No. 94, which is about half a mile north of the travellers' bungalow.

Bed-rock Corundum.

The only rock seen *in situ* was a disintegrated and much altered hornblende-gneiss. The corundum is of a dark brown colour, more nearly resembling that of Paparapatti than anything else. There was a fairly large quantity of it scattered over the field, the few of us present easily picking up pieces of the size of walnuts. Old picked-over heaps of rubbish lined the edge of the field. The Revenue Inspector informed me that this was the only field near in which the mineral was found; that a contractor from Madras came annually and took away all the corundum he could find; that the latter employed 30 or 40 coolie women who worked for three months last year (1894) and collected altogether two large cart-loads; that each woman could collect $\frac{1}{2}$ to 1 Madras measure (= Rs. 80 weight) every day.

This field struck me as being singularly productive. The rock beneath is probably very rich.

(7) *Karutapalaiyam.*

Locality.

The above village lies about two miles W. N. W. of Sivamallai, a prominent temple-crowned hill in the Kangyam taluk. Between the village and the hill there stretches a row of six or seven small rocky hillocks composed of the same gneiss as the hill itself. The hillocks in fact are structurally a W. N. W. continuation of the Sivamallai mass.

The neighbouring rocks.

Two rocks of different composition and structure are connected with the appearance of corundum at this place. The one is the pale grey gneiss of the Sivamallai hill, and the other a coarse granite intruded as veins into the gneiss.

The former is a very felspathic rock which in appearance resembles the anor-

thite rock of Sittampundi. It is composed almost wholly of plagioclase felspar and microcline in a granular condition. A small quantity of biotite or of hornblende and iron-oxide, with another minute mineral in small octahedra, zircon (?), occur as accessories. The last was brought to me as corundum by some of the Sivamallai villagers.

The whole rock weathers into large pale ochre-coloured blocks forming small tors.

Along the northern foot of these hillocks, between Karutapallaiyam and the Tiruppur-Kangyam road and extending for a distance of one mile, there are a series of holes and trenches made by the owners of the lands, which reveal the coarse granite alluded to above. It is a dark red, white, and black non-foliated rock, composed of red or deep flesh-coloured felspar which is a form of orthoclase with minute intergrowths of probably plagioclase, quartz, in sometimes very clear lumps, and biotite in large nests of small plates.

The corundum occurring in the coarse granite.

It is in this extremely coarse red granite that the corundum is found as large, well-preserved, six-sided crystals of a dark or light greenish-grey colour. The mineral appears in this completely unaltered rock as if it were a normal mineralogical constituent, or at least accessory, of the granite. It possesses no shell of any other mineral as in the case of the Sittampundi and other localities where the corundum is found in its matrix. There is nothing to suggest in this case that the corundum was formed subsequently to the matrix in which it lies; nothing to suggest a secondary origin for it.

This area is still under investigation, but in the meanwhile it is noteworthy that corundum is dug chiefly in the granite along the line of contact (or very near it) with the gneiss.

This is not the place to introduce theories; but should the mineral be afterwards shown to be a contact phenomenon, then its presence in the gneiss at Sittampundi as a secondary mineral, and its presence in the granite of Sivamallai as one of the same age as its matrix, would be explained.

Mining the corundum: numerous holes and trenches.

The mining or digging out of the corundum near Karutapallaiyam is quite an active industry (1895) on a small scale. The fields on the northern side of the row of rocky hillocks of waste land have been taken up, not for the purpose of cultivation, but for corundum mining. There are a number of irregular holes and some few regular trenches, the latter following W. by N.—E. by S. (the direction of strike of the gneiss and of the intrusive veins of the granite) or at right angles to this direction. One of these was 30 yards long, 2 yards wide, and 20 feet deep. Another trench was dug along a direction N. E. by E. for 15 yards. It was 20 feet deep and 2 yards wide, and it followed the junction of the granite with the gneiss which here dipped 60° N.W. The largest and most productive working was close to the village of Karutapallaiyam. Here were obtained some very large crystals of corundum 6—8 inches across. I was shown a basketful of the mineral weighing about 14 seers (28 lbs.) gathered during the day of eight hours by four men, their wives and little children.

A past generation are reported to have made a very good thing out of the corundum of this place, when the stuff sold for Rs. 40 per podi = 192 Madras measures.

Now, I was told, only Rs. 30 would be obtained for the same amount; I cannot say how much confidence is to be placed in these figures.

On the whole I think this locality is perhaps the most promising that I have so far seen. It is the only one I saw in private land that was in active working.

Other localities near this place.

At Padyur, Shigrispalaiyam and Kundyankovil in the vicinity the mineral is reported. They will be visited in due course.

SUMMARY AND GENERAL REMARKS.

Varied matrix of the corundum.

From the preceding account, it is clear that the corundum deposits of Salem and Coimbatore, so far as they have been at present examined, are not confined to one well-marked stratum of rock, of a constant composition and definite horizon. The matrix may be, as we have seen, (1) anorthite gneiss, (2) orthoclase gneiss, (3) a fine-grained schist, (4) a coarse graphic granite.

Thus the nature of the bed-rock of any area would not be a guide as to whether corundum might be found there or not.

It seems possible, however, that the presence in or near of a coarse granite, intrusive among the bed-rock, does represent a condition without which corundum fails to appear. Further discussion of this point is reserved at present.

Mode of distribution of the mineral in its various matrices.
A scattered distribution.

Throughout the seven areas already examined the mode of distribution of the mineral in the matrix is generally the same, that is to say it is a scattered distribution; the crystals, lumps, or grains are dispersed at intervals through the rock-like plums in a pudding, or porphyritic crystals in an igneous rock. The particulars of this distribution in the various cases under notice are of practical importance. (1) The richness of the rock varies within certain limits (which cannot be obtained without a prolonged practical test. (2) The presence or absence of a shell of a softer mineral, *e.g.*, calcite round the corundum, determines the ease or otherwise with which it can be extracted pure from the rock. For instance the Sittampundi rock is poorer than the Karutapallaiyam rock, but the former can be got out nearly pure whilst a heap of the latter is generally half felspar.

No beds of massive corundum as at Rewah.

Nowhere in the areas that I have seen does the mineral become massive and aggregated into layers or beds as in the well-known Rewah deposits of Pipra, described in 1872—1873 by Mallet (*Records G. S. of India*, vol. V., p. 20, and vol. VI., p. 43), where a bed of several yards thick (maximum thirty yards) is traceable for ½ mile.

As all corundum must be reduced to a granular coarse powder before it can be used by lapidaries, etc., it is open to question whether a scattered distribution or a massive occurrence is the more easily manipulated form. Massive corundum would certainly present difficulties to the simple form of working adopted at present by the natives of Salem and Coimbatore.

It may be mentioned that the so-called "sand vein" of corundum at Culsagee and Laurel Creek, United States, which is loose and incoherent, and can be worked by the hydraulic process, is preferred to the more massive crystalline lumps, as it saves the labour of pulverizing (see Mineral Resources of U. S. by T. M. Chatard, p. 714).

Gem forms of corundum.

At Sittampundi, rubies have been found as detailed before in this report. Sapphires are also mentioned by Newbold as having been found in the valley of the Cauvery (*Journal, Roy. Asiatic Soc.*, vol. VIII., p. 153). This is rather a wide field, and so far I have been unable to corroborate the statement.

Corundum occurrences in these districts similar in appearance to that of the sapphires in Zanskar.

It may be mentioned, however, that the form and shape of the crystals in the Paparapatti and Karutapallaiyam areas and their mode of distribution very much resemble the like conditions under which the sapphires of Zanskar in Kashmir appear. In our area the colours differ by being of a dark greenish or reddish grey, whilst in Zanskar, they are of a bluish grey, which locally becomes a deep violet-blue (sapphire). The colouring of such minerals, depending as it does on accidental impurities in them, may easily vary. The finding of sapphires in the corundum areas of Salem and Coimbatore is therefore quite possible.

Inexhaustible supply of corundum.

The mode of occurrence of the corundum in Salem and Coimbatore in rock masses which appear only at intervals above the alluvium, but which have a very extended distribution, shows that the area of productive rock is practially inexhaustible. As a petty article of commerce, therefore, so long as corundum is used in the arts, it will be worked in a desultory way. Whether it will ever rise to be an important item in the trade of the Presidency or not, depends on so many causes and conditions of demand, labour, opportunity, fashion, capital, boom, etc., that I can give no opinion thereon.

On the occurrence of blue Corundum *and* Kyanite *in the* Manbhum District, Bengal. *By* H. WARTH, D.SC., *Deputy Superintendent, Geological Survey of India.*

Near the village of Salbanni, four miles east-south-east of Balarampur on the Bengal Nagpur Railway, I found in October, 1895, a large vein of kyanite with blue corundum exposed in a road-cutting. The vein follows the strike of the rocks and the boundary line between the transitions and metamorphics, running a little to the south of east. This boundary is described in Ball's memoir on Manbhum and Singbhum as being formed by a fault rock of pseudomorphic, and sometimes massive, quartz, which contains much limonite and in some places copper.

The kyanite occurs with micaceous beds in coarse-grained quartz-rock, which forms here a slightly elevated broad ridge parallel and close to the boundary, about one-fourth mile to the north of the ridge of fine-grained splintery quartzite with which the transition rocks terminate.

The coarse-grained quartz-rock contains much tourmaline, rendering whole beds of the quartz banded or entirely black. Tourmaline is also abundant in the quartzite which extends about one mile further from the kyanite vein on the side of the

metamorphics. These quartzites are invaded by a number of small veins of pegmatite associated with schist and dykes of hornblendic rocks. On the other side of the boundary I found the usual association slate and quartzite which constitute the transition area to the south-east of Barahabhúm. The quartzite forms at the boundary a straight ridge parallel to the strike of the rocks, running for a mile or more with a constant bearing of E. 10° S. and W. 10° N., whilst the dip is to northwards. Dioritic intrusive rocks which are abundant were seen in one case to follow the strike of the bedded rocks and even to weather and peal off in the direction of the strike.

Near the kyanite vein I also found on the surface of the ground occasional crystals of rutile. They were well developed, tetragonal combinations, sometimes half an inch in thickness, sometimes forming geniculate twins. The kyanite vein shown in the road-cutting near Salbanni is about two feet thick, and the crystals measure sometimes nine inches in length and are of a pale and sometimes variegated blue colour. They are intergrown with colourless mica and crystals of corundum. The latter crystals are usually simple tapering prisms from half an inch to three inches in thickness, and are arranged without discoverable crystallographic regularity in the kyanite. A layer of mica, one-eighth to one-fourth inch thickness, usually forms a coating between the corundum and the kyanite. The corundum is of an exquisite deep blue colour. Some of the largest crystals, one particularly of six inches length and 3℔ in weight, being of dark sapphire blue throughout. Others are blue at the margins and colourless in the centre, and in still others the colouring is irregularly distributed, a feature characteristic of real sapphires such as occur in Cashmere. Small portions of some of the blue crystals are transparent, but in the majority the transparency is destroyed by cleavage and twinning planes.

The kyanite vein was traced to a distance of three miles on either side of Salbanni. The greatest thickness of the vein was observed about one mile to the west-north-west of Salbanni near the village of Girgirdeeh. Some blocks were here exposed which were parts of a vein 40 inches thick. The blades of kyanite were vertical to the walls of the vein, and on both sides as well as in the middle there was a 2-inch layer of mica. I also observed tourmaline, but the corundum occurred only in traces.

Corundum was also observed near the village of Gobindpur, about two miles west-north-west of Salbanni. In the opposite direction I examined the section along the road from Barahabhúm direct to Purulia. Neither kyanite nor corundum however were observed, but this might be due to accidental covering by alluvium, and the whole of the boundary would have to be examined before the corundum and kyanite occurrence could be limited with certainty to the above-mentioned length of six miles.

On the papers by DR. KOSSMAT[1] and DR. KURTZ,[2] *and on the ancient Geography of "Gondwána-land," by* W. T. BLANFORD, LL.D., F.R.S.

Translations of two important palæontological papers have appeared in the second and third parts respectively of the 'Records' for 1895. The first, by Dr. Franz Kossmat, deals with "the importance of the cretaceous rocks of Southern India in estimating the geographical conditions during later cretaceous times," the second, by Dr. F. Kurtz, contains an extract from "contributions to Argentine Palæophytology," and treats of "the existence of the Lower Gondwána flora in the Argentine Republic."

At the first glance it would almost appear as if the first paper had but little connection with the Geology of India, and the second paper none at all, and in one sense this is true. But there is nothing more remarkable in the history of Indian Geology for the last 30 or 40 years than the light which has been alternately shed upon India by discoveries in other countries, especially in the continental masses of the southern hemisphere, and reflected from India upon the southern continents. Dr. Kossmat's paper confirms in the strongest and most convincing manner a theory suggested by certain details of Indian cretaceous palæontology, and traced out originally by Indian Geologists, and Dr. Kurtz's discovery makes known a great extension in upper palæozoic times of the southern continent, of which India formed part, and which is widely known by an Indian name, the Gondwána land of Suess.

There are points in both papers on which a few remarks may be added. This is especially the case with Dr. Kurtz's paper, because there are other recent discoveries in South American Geology of interest to Indian Geologists. It is, however, convenient to refer to Dr. Kossmat's paper first, as it was the earlier in date, and the first remark to be made may be regarded as a criticism.

DR. KOSSMAT'S PAPER.

Dr. Kossmat appears to have overlooked the fact that the distinction of the uppermost portion of the cretaceous system, the beds with *Nautilus danicus*, as the Ninnyur group, the original suggestion of which distinction he attributes to Mons. H. Leveillé, in 1889[3] was clearly indicated in my brother's (Mr. H. F. Blanford's) original memoir,[4] and still more distinctly in the "Manual of the Geology of India."[5] In fact M. Leveillé took all his data about the Ninnyur group from the Manual, for he expressly stated that in the ground examined by him near Pondicherry he was unable to distinguish the two groups, Ariyalur and Ninnyur, although he believed that both occurred. That the Ninnyur beds should be separated from the Ariyalur groups as a higher subdivision was, I know, my brother's decided

[1] *Records*, Vol. XXVIII, Pt. 2, p. 39.
[2] *Ibid.*, Pt. 3, p. 111.
[3] *Bull. Soc. Geol., France.*, XVIII, p. 146.
[4] *Mem., Geol. Surv., Ind.*, IV, p. 141 (1862).
[5] 1st Ed., p. 287; 2nd Ed., p. 243.

opinion, for I have often heard him speak on the subject. That the Ninnyur beds have not been more clearly distinguished in the *Palæontologia Indica* is probably due to the fact that the magnificent description of the South Indian cretaceous fossils is an unfinished work. It had always been Stoliczka's hope and expectation (as was mentioned in the Manual, 1st Ed., p. 273, foot-note), after finishing the description of the collections made by the survey, to visit the localities from which they were derived, and to study the rocks, which he had never seen on the ground. Had he done so, questions like the separation of the Ninnyur beds and the relations to each other of the Valadayur and Ariyalur beds of Pondicherry would have been decided long since. Unfortunately Dr. Stoliczka's description of the South Indian cretaceous fauna was only completed just before his departure in 1873 with the Mission to Yarkand, which proved fatal to him.

As regards the union of the Ariyalur and Valudayur beds of Pondicherry, in favour of which Dr. Kossmat expresses himself very strongly, it should not be forgotten that in the area mentioned the beds dip at low angles and are very rarely seen, being greatly concealed by surface accumulations, also that the majority of the fossils have been picked up on the surface of the ground in a way that renders it difficult, unless their origin can be determined by mineral character, to say exactly from what bed they have been derived. My brother came to the conclusion that the two groups were distinct, after a thorough examination of the ground, and pointed out (*Mem., G. S. I.*, IV, p. 155) that the Valudayur beds differed both lithologically and palæontologically from the overlying Ariyalurs, and that the latter contained pebbles derived from the former. The great advance that has taken place in the knowledge of cretaceous ammonites since my brother and Stoliczka wrote, may fully justify Dr. Kossmat's conclusion that the Valudayur beds are not of Utatur age but newer, without proving that they should be united with the overlying Ariyalur strata. It is never quite safe to reject conclusions formed on examination of rocks in the field without re-examination.

These questions, however, though of local interest, are comparatively trivial. The importance of Dr. Kossmat's paper to Geology in its truest and highest sense—to the history of the world—is due to the manner in which, by a masterly study of the distribution of ammonites and other cephalopoda, he has traced out the old coast-lines of cretaceous continents and has confirmed the opinion expressed in the Manual of 1879[1] that a land barrier must have extended in cretaceous times from India to South Africa[2] across the Indian Ocean, and that the cretaceous beds of Trichinopoly and those of the Nerbudda were on opposite sides of this barrier.

Since its first publication various discoveries have contributed to support the view just noticed. The evidence brought forward in favour of a land connection between India and South Africa, by way of the Maldives and Mascarene islands, in both newer palæozoic and mesozoic times, was strongly confirmed by Neumayr's[3]

[1] Introduction, p. XXXIX, also remarks on pp. LXVIII and LXXII, also p. 297.

[2] In the translation of Dr. Kossmat's paper, *Records*, XXVIII, p. 42, "Die Annahme einer ehemaligen Landverbindung zwischen Sudindien and Hochafrica" is represented by "the theory of the former existence of land between the south of India and the north of Africa. I would suggest that by Hochafrica Dr. Kossmat means the African highlands, not the north of Africa. There is land connection between Southern India and Northern Africa at the present day.

[3] *Denkschr. K. K. Ak. Wiss. Wien, M. N. Kl. Bd.* I (1885), p. 132, map 1.

perfectly independent evidence from jurassic data, published in 1885, and in 1890 I brought[1] forward some additional facts, mainly zoological, leading to the same conclusion. Lately a very remarkable addition to the evidence has been furnished by Admiral Wharton, Hydrographer to the Admiralty. In his Presidential address to the Section of Geography in the British Association at Oxford[2] he points out that the north-western part of the Indian Ocean is apparently cut off from the main oceanic basin by a shallow belt probably extending from the Seychelle Islands to the Maldives, it being of course understood that the Seychelles are also connected by comparatively shallow tracts with Madagascar and Africa and the Maldives with India. The isolation of the north-western basin is inferred from the warmer temperature of the deep water. It is a well-known fact that where free circulation takes place between the depths of tropical and temperate oceans and the seas of Arctic or Antarctic regions the bottom temperature is much lower than when belts of shallower water intervene to prevent the heavy cold currents of arctic derivation from flowing into any oceanic tract.

There is no more certain test of theory than independent evidence. In this case the inference from purely palæontological data that a belt of land must have connected India with South Africa in pre-tertiary times has already received some confirmation from the present distribution of animals, and now, from a totally different quarter, and from a branch of scientific enquiry entirely unconnected with biology or geology, comes this striking confirmation of the original hypothesis. It is scarcely necessary to point out that if, in cretaceous times, a land area extended from India to Africa, and if sufficient depression took place in the tertiary era to submerge the whole of the connecting tract beneath the sea, just such a comparatively shallow barrier between the depths of the main Indian Ocean and its north-western portion would probably remain, as is now indicated by the temperature of the deep water.

Another most interesting part of the evidence brought forward by Dr. Kossmat is that relative to the distinctions between the cretaceous fauna of the Atlantic coasts of America and the contemporary fauna of the Pacific, the latter, as was shewn by Stoliczka to some extent, being intimately connected with that of India. The resemblance of the cretaceous faunas in India and California, it may be remembered, is by no means confined to cephalopoda. The natural inference would appear to be that North and South America were united in cretaceous times. It is evident that the union was broken up very early in the tertiary era, for the eocene mammals of Argentina are quite different from those of the United States, and it is not improbable that temporary connections during small portions of cretaceous time between the Atlantic and Pacific, rather than persistent arms of the sea from one ocean to the other, may account for some of the occurrences of Atlantic forms on the Pacific Coast to which Dr. Kossmat refers, as in the similar case of identical upper jurassic or lower neocomian fossils (*Trigonia Smeei*, *T. ventricosa*) occurring on both sides of the Indian Peninsula. The question of the ancient Physical Geography of the great western continent is, however, of secondary importance to Indian geologists.

[1] *Quart. Jour., Geol. Soc. Proceedings*, pp. 88-99.
[2] *Rep., Brit. Assoc*, 1894, p. 706.

DR. KURTZ'S PAPER.

Before passing on to any remarks on the discovery in Argentina, I should add that I have learned from Mr. Griesbach that important additions have been made, since the publication of Dr. Kurtz's paper, to the number of Lower Gondwána plant-fossils that have been found there. These must add greatly to the importance of the flora and can scarcely fail to throw some additional light on its affinities and perhaps on the distribution of land in upper palæozoic times.

Meantime it may be useful to recapitulate the principal facts already ascertained concerning the occurrence of plants with Gondwána affinities in South America. It was known as long since as 1876,[1] that an *Estheria*, identified with that found in the Kámthi beds at Mángli, south of Nágpur, together with certain fossil plants, regarded as of rhætic age, had been found in the Argentine Republic. The plants were the following:—

ALGÆ:
- *Chondrites mareyesiacus*, Gein.

FUNGI:
- *Xylonites sp. Conf. X. Zamitæ*, Göpp.

FILICES:
- *Thinnfeldia crassinervis*, Gein.
- *Th. ? tenuinervis*, Gein.
- *P. chypteris stelzneriana*, Gein.
- *Otopteris argentinica*, Gein.
- *Hymenophyllites mendozaensis*, Gein.
- *H.* sp.
- *Baiera*[2] *tæniata*, Braun.
- *Pecopteris tenuis*, Schouw, Brogn.
- *Tæniopteris mareyesiaca*, Gein.

CYCADEAE:
- *Pterophyllum oeynhausianum*, Göpp.

CONIFERAE:
- *Palissya brauni*, Endl. var. minor, Gein.
- *Sphænolepis rhætica*, Gein.

There were also found scales of *Semionotus* (a Ganoid fish).

Of these plants *Baiera tæniata, Pterophyllum œynhausianum* and *Palissya brauni* were represented as identical with European rhætic plants and *Pecopteris tenuis* with a liassic form. No species was at first identified with any form belonging to the Indian or Australian fossil flora. As regards *Estheria mangaliensis*, the discovery of which in Argentina was prominently noticed in the Records by Dr. Feistmantel,[3] no great weight can be attached to the identification of these small crustaceans, of which many closely-allied species have been described. Thus the connection between the "Rhætic" flora of Argentina and the

[1] Beitrag zur Geologie u. Palæontologie der Argentinischen Republik. Palæontologische Theil, II Abth. Ueber rhætische Pflanzen u. Thierreste in den Argentinischen Provinzen La Rioja, San Juan und Mendoza. Von Dr. H. B. Geinitz. Cassel. 1876.

[2] This genus is now regarded by many palæobotanists as a conifer allied to Gingko (*Salisburia*).

[3] *Rec. G. S. I.*, 1877, X, p. 26.

Upper Gondwana flora of India was quite insufficient at the time when the first edition of the "Manual" was published in 1879 to deserve notice.

In fact the first addition to our knowledge of the Argentine flora that had a really important bearing on its Gondwána affinities was the identification in 1880 by Nathorst of *Thinnfeldia crassinervis*, Gein. with *Pecopteris odontopteroides*, Morris, an identification confirmed by Feistmantel[1] who had already pointed out the similarity of the two forms. The importance of this fossil plant, which appears to be as widely distributed in the upper Gondwánas as *Glossopteris browniana* is in the lower, was at that time gradually attracting attention, as the same species had been found, although rarely, in India, and its occurrence had just before been noticed in the Stormberg beds of South Africa, in which it appears to be as common and characteristic as in the Hawkesbury beds of Australia and in the "Rhætic" of Argentina.

The next noteworthy contribution to our knowledge of Argentine fossil botany was by Dr. Szajnocha in 1888.[2] He described a collection from Cacheuta in the province of Mendoza containing the species below enumerated.

Equisetaceæ.
Schisoneura hoerensis ? Hisinger.
Filices.
Sphenopteris elongata, Carruthers.
Pecopteris Schönleiniana, Brogn.
Neuropteris remota ? Presl.
Thinnfeldia odontopteroides, Morris.
Thinnfeldia lancifolia, Morris.
Tæniopteris mareysiaca, Geinitz.
Cardiopteris Zuberi, n. sp.
Cycadeæ.
Podozamites aff. ensis, Nathorst.
Podozamites schenckii, Heer.
Zeugophyllites elongatus, Morris.

Besides fragments of *Pterophyllum* and *Ctenophyllum*, and *Estheria mangaliensis* in abundance.

The plants described by Geinitz were found in several localities, the beds at some of which, as Dr. Szajnocha pointed out, were perhaps of rather later date than those of Cacheuta. This, however, is not of much importance. The striking fact is that amongst the eleven species identified by Szajnocha, no less than five, *Sphenopteris elongata*, *Pecopteris schönleiniana* (*P. lobifolia* Morr.), *Thinnfeldia odontopteroides*, *T. lancifolia*, and *Zeugophyllites elongatus*, are characteristic Australian types, and that several of them occur in the upper Gondwána of India and in the Stromberg beds of South Africa.

Then, in 1888, a letter from Mr. Orville A. Derby, Director of the Geological Section of the National Museum at Rio de Janeiro, was published by Dr. Waagen,[3] who, it will be remembered, had, in the previous year, written an important paper on the Carboniferous Glacial period (*Carbone Eiszeit*), of which paper a translation appeared in the Records for 1888, p. 89. In this paper (Records, t. c., p. 129)

[1] *Pal. Ind.*, Ser. XII, vol. III, pt. 2, p. 85.

[2] Ueber fossile Pflanzenreste aus Cacheuta in der Argentinischen Republic. *Sitzungber. K. Akad. Wiss Wien*, Math. Naturw. Cl. XCVII. Abth. 1, p. 219.

[3] *Neu. Jahrb. f. Min.*, etc. 1888, II, p. 172. Translated in *Records*, *G. S. I.*, 1889, p. 69.

Waagen stated that, so far as he was aware, South America was the only continental mass in which glacial formations had not been observed, either in carboniferous or permian deposits. Mr. Derby, however, described certain beds of carboniferous age, in the province of San Paulo in Southern Brazil, containing rolled pebbles from the size of a fist to quadruple the size of a man's head, embedded in the finest shale; in another place in the same province, near the town of Itu, isolated rounded blocks, some of them a foot and a half in diameter or more, in excessively fine sandy shale. In yet another place even larger blocks, apparently derived from shale, were seen, some of them more than a metre in diameter and consisting of gneiss, granite, and hard conglomerate all mingled together. In short, there can be very little doubt that the beds discovered by Mr. Derby exhibit the characteristic features of the Talchir boulder bed, and if the peculiar character of the latter is due to glacial agency, the same agency must have influenced the formation of the Brazilian deposit. The boulder beds of San Paulo are 300 or 400 miles north of the localities in Rio Grande do Sul, where fossil plants have been discovered, but so far as can be judged from Mr. Derby's papers the formation is the same.

And now these discoveries, one after the other, of the exceptional characters that have made the Indian, Australian and South African beds famous in the history of Geological Science, have been completed by the recognition in South America of that remarkable and characteristic flora which first drew attention to the whole question. It is curious how the typical forms of the Lower and of the Upper Gondwanas have been gradually traced in India, Australia and South Africa, how in each case a peculiar boulder bed has been found associated with them, and how every one of the same peculiar features has now been met with in South America. Not the least remarkable fact, moreover, is the peculiarly Indian facies of the Argentine flora, the association of *Neuropteridium validum*, Feistm. *Gangamopteris cyclopteroides*, Feistm., and *Noeggerathiopsis hisolpi*, Feistm., being characteristic of the Karharbari beds of Western Bengal, and one of the species *Neuropteridium validum*, not having hitherto been found in Australia or South Africa so far as I am aware.

It has long been understood that coal-bearing beds with *Lepidodendron* and other fossil plants of the ordinary northern carboniferous type occur in southern Brazil. What these plants really are will appear presently, but their existence made it far from remarkable that lower carboniferous (culm) forms should be discovered in Argentina. The latter were described by Szajnocha [1] in 1891, and some additions have recently been made by Dr. Kurtz. The principal forms belong to the genera *Archæocalamites*, *Lepidodendron*, *Rhacopteris*, *Cordaites*, and *Bodrychiopsis* and shew considerable similarity to plants from the same horizon in Australia, though not the same amount of identity as is exhibited by the Upper and Lower Gondwána fossils.

On one occasion before this the occurrence of a Lower Gondwána flora in South America appears to have been noticed. This was by Dr. A. Hettner[2] in 1891. He described the coal measures of southern Brazil, and stated that he had obtained from them fossil plants belonging to the *Glossopteris* flora.

[1] *Sitzungsb. Kais. Akad. Wiss. Wien.* Math-naturw. Cl., Vol. C, Abth. I, p. 199.
[2] *Zeitschr. d. Gesellsch. f. Erdkunde*, XXVI, pp. 91, 124.

Nearly 30 years ago, Mr. N. Plant brought from the southern parts of the province of Rio Grande do Sul, the southernmost part of Brazil, a number of fossil plants, of which three species were described by Mr. W. Carruthers[1] as :—

Flemingites pedroanus.
Noeggerathia obovata
Odontopteris plantiana.

The plants have always been regarded as typically carboniferous, and to this, so far as geological age is concerned, there can be no objection. But quite recently Prof. R. Zeiller[2] has pointed out that, whilst the *Flemingites* is clearly a form of *Lepidodendron*, *Odontopteris plantiana* bears a certain resemblance to *Neuropteridium validum*, and *Noeggerathia obovata* offers a remarkable similarity to *Euryphyllum whittyanum*, another Karharbári fossil plant. He also adds that he has examined the specimens noticed by Dr. Hettner as pertaining to the *Glossopteris* flora, and has ascertained that they comprise *Gangamopteris cyclopteroides* var. *attenuata* associated with *Lepidophloios laricinus* and a *Lepidodendron*.

The remarkable discoveries in South America succeed each other with such rapidity that it is difficult to grasp their import. Quite recently I heard from Mr. Griesbach that Dr. Kurtz had found a *Lepidodendron* associated with the Glossopteris flora in Argentina. The same appears to be the case in southern Brazil, and strange to say the evidence has been on record since 1869, though, until Prof. Zeiller re-examined the facts, their real importance was unsuspected. It is one of the weird tricks of fate that Mr. Carruthers, who has persistently held the doctrine that the *Glossopteris* flora belongs to a much later period of the world's history than the *Lepidodendron* flora of the coal measures, should himself have been the first to describe, without knowing it, a group of fossil plants containing representatives of both and affording parts of the conclusive proof that the two co-existed.

It should not be forgotten that this discovery of the association in the same bed of the Gondwána and carboniferous flora is something very different from the curious mixture of Upper and Lower Gondwána types described some years ago by Prof. Zeiller from Tonquin,[3] because the European forms there found associated were liassic or rhætic, and some of these are commonly met with in Upper Gondwána beds.

When a large tract in a distant continent has been annexed to one of the great Empires of the world, some time elapses before the importance of the new colony is fully recognised. It is the same with our latest addition to Gondwána land. A glance at the Globe, or at a map of the South Polar area, will shew how the addition of South America up to the Tropic of Capricorn changes the general aspect of the region with which the Gondwána flora has hitherto been associated.[4]

[1] *Geol. Mag.*, 1869, p. 151, pls. V, VI.

[2] *C. R.*, Dec. 16, 1895; *C. R. Séances. Soc. Geol., France*, 1895, p. CXCVII.

[3] *Bull. Soc. Geol., France*, Ser. III, Vol. XI, p. 456.

[4] If the beds of San Paulo are really of glacial origin, it is clear that Mr. R. D. Oldham's proposal (Manual, 2nd Ed., p. 212, and references there quoted) to explain the remarkable occurrences of upper palæozoic boulder beds in India by a change in the direction of the Earth's axis and in the position of the poles must be abandoned. The subject has been treated by Neumayr (*Erdgeschichte*, Vol. ii, p. 197) who shews (of course without taking the discoveries in South America into consideration) that, assuming the most favourable position for the South Pole, the places in North-Western India, South Africa, and South-East Australia, where boulder beds are known to occur, would all be in comparatively low latitudes within 30° to 35° of the Equator. As Neumayr himself suggested a change in the direction of the

From a number of circumstances connected with the distribution of life it has for some time been suspected that connections between certain of the southern continents and the Antarctic land must have existed at times. One of the most remarkable facts in favour of this conclusion is the discovery in Argentina of remains of marsupial carnivora related to those now living in Australia, no similar forms having hitherto been detected amongst the fossil remains of the northern hemisphere.

It does not necessarily follow that the whole area in which the Gondwána flora has been discovered was part of one unbroken continental tract at the same time. There is no doubt that seeds of some plants survive transport by sea, and spores of ferns may be carried to a considerable distance by wind. At the same time it is probable that there was either actual land connection or a near approach to it, whilst there can be no question that some barrier must have interposed between the tracts in which the dominant forms were *Lepidodendron* and *Sigillaria* and the lands of the *Glossopteris* flora. The barrier may have been the Thetys of Suess,[1] that ocean of which the Mediterranean of the present day is a shrunken relic, and it is not without interest to observe that the recent re-examination of the pelagic trias fauna, by Mojsisovics, Waagen, and Diener,[2] has led to the conclusion that the outlines of the Pacific Ocean were laid down in pre-triassic times, whilst the contours of the Atlantic and Indian Oceans are of more recent dates. And here may be noted one of those curious side lights thrown upon these very interesting questions of ancient geography from a totally different source. In the same Presidential address to the Geographical Section of the British Association at Oxford, to which reference has already been made, Admiral Wharton shows how two waves caused by the eruption of Krakatoa in 1883 were noticed by a French observing party at Cape Horn, and how it was ascertained that one of the waves which came from the westward or by the Southern Pacific arrived sooner than the other which travelled by the Indian and Southern Atlantic Oceans, each wave having to pass round the Antarctic land and the distance being nearly the same in each case. It was shewn that the retardation of the western wave was probably due to the shallower water of the South Atlantic, a condition which is consistent with the hypothesis that there may have been land in that area, whilst the Southern Pacific was part of the great ocean.

The discovery, in several different parts of South America, of *Gangamopteris* and *Neuropteridium*, associated in the same beds with *Lepidodendron*, may perhaps imply that a land connection existed in newer Palæozoic times in the American area between the continent of the northern hemisphere and Gondwána land. But further information is required before this view can be accepted. If there is really a commingling of the *Lepidodendron* and *Glossopteris* flora in Southern Brazil and Argentina, several additional representations of the rich coal-measure flora of Europe and North America will assuredly be discovered in the area. At the same time it is important to note that in South America, for the first time, representatives of the two great floras are found associated in the same beds, and a final and conclusive proof afforded of their contemporaneous existence.

Earth's axis in miocene times to account for the peculiar flora of Japan, he had no prejudice against the hypothesis.

[1] *Natural Science*, March 1893, p. 183.

[2] *Sitzb. K. Akad. Wiss. Wien.* Math-natur Cl., CIV, Abth. I, p. 1302 (Dec. 1895).

Notes from the Geological Survey of India.

Gondwana rocks.

REWAH.—The party under the superintendence of Mr. Oldham have continued the mapping of the Gondwana areas in South-East Rewah. The Talchirs, previously marked by Mr. Smith, were found near the western limit of sheet No. 476 (lat. 24°12', long. 82°21') to lie in a very flat synclinal, resting on an irregular surface of schists, and not more than 100 feet in thickness. Less than a mile away, beds of Upper Gondwana age were found resting directly on the granite. The occurrence of these strata in immediate contact with the granite, without the intervention of the Talchirs or Damudas, and so close to the Talchir rocks, indicates a great unconformity somewhere between the two. It remains to be determined whether this unconformity is above or below the Damuda series. Not the least interesting find in connection with the work in this area is the occurrence in the Talchir boulder-bed of smoothed and striated boulders, similar to those resulting from the action of modern glaciers. A large area has been added to the known outcrop of the Damudas, together with the determination of several seams of coal, from amongst which a fair collection of fossils has been made.

Crystalline rocks.

MADRAS.—Mr. Middlemiss, assisted by Mr. Smith, has largely extended the recorded occurrences of magnetite and hæmatite beds in the northern taluks of Salem and Coimbatore districts. Several new corundum localities have also been discovered in the Hosur taluk of the Salem district, which are both interesting and economically important, forming a structural continuation northwards, as anticipated in a paper in the present number of the Records (p. 43), of the promising outcrops near Paparapatti in the Dharmapuri taluk of the same district. The Bargur hill range in Coimbatore district was found to form one great *massif* with the hills north of Satyamangalam, and are composed of various members of the interesting hypersthene-bearing series first noticed in South India by Mr. Holland in 1892, and similar to the main masses of the Shevaroys, Nilgiris, Palnis and other large hill-masses of the Madras Presidency. The hypersthene-bearing rocks of the Bargur hills under consideration are well-foliated, having a foliation strike of NNE.—SSW., which would carry them across the Satyamangalam-Bhavani plain, the prevailing gneisses of which, however, are of a totally different composition. Although this sudden appearance of the hypersthenic series along a line making a considerable angle with their foliation-strike is at present a question unsolved, it is not without significant bearing on Mr. Holland's conclusion, as the result of a rapid tour over the Southern Presidency, that the peculiar phenomena exhibited by these rocks in the field and under the microscope can best be explained as the result of circumstances similar to those attending the intrusion and consolidation of the more generally recognised plutonic types of igneous rocks.

1. Crystalline rocks.

BURMA.—Mr. Hayden has recorded some interesting facts in connection with his survey of the Sagyin ruby-tract. The crystalline limestone, in which such minerals as ruby, spinel, rubellite and schorl occur, is found to be separated from the gneisses by a conglomerate composed of blocks of limestone, gneiss and quartzite. The gneiss near this

junction is highly graphitic and much decomposed. In the country to the N.E. of the Sagyin hills the gneisses and quartz-rock are associated with a siliceous rock, which gradually becomes more calcareous until it passes into limestone, and this is succeeded by further siliceous bands and a rich and valuable graphite-bearing gneiss.

2. *Tertiary rocks.*—Mr. Hayden has examined the Mithwe coalfield of Upper Burma in which he finds the Tertiary shales, sandstones and conglomerates with thin seams of coal to be greatly compressed by earth-movements, as well as altered by the intrusions and outflows of a diallage-rock approaching gabbro and serpentine.

PETROLOGICAL NOTES.—Whilst classifying the collection of rocks in the Museum, Mr. Holland has found that the contemporaneous lava-flows of the Transition systems of India exhibit some interesting similarities in their microscopic characters. So far as they have been examined at present they seem to be divisible into three main groups:—

1. Volcanic rocks of the Transitions.

(1) Contemporaneous flows of the Dharwar system, which originally were pyroxene-plagioclase rocks; but now generally converted into epidiorites and hornblende-schists.
(2) The olivine-bearing Jootoor lava-flow of the Kadapahs.
(3) The pyroxene-plagioclase rocks with micrographic quartz, occurring as lava-flows in the Kadapahs, Gwaliors and Bijawars.

The *first group* (the Dharwar group) seems to have its corresponding series represented in the Transitions of Manbhum and Singhbhum in S.W. Bengal, and the dioritic dykes of the same area.

The *second group* forms an extremely interesting set of rocks in which olivine, enstatite, augite, biotite and plagioclase form the constituents. The plagioclase is generally in small quantity, when the rock approaches the saxonites in composition; it is the last formed mineral, growing ophitically around the ferromagnesian constituents and forming a well-defined reaction border where it comes in contact with the olivine. A beautifully clear specimen of this rock, occurring as a dyke in the crystallines, was collected by Mr. Datta in South Rewah during the season 1894-95, and Mr. Holland has found a similar rock occurring as dykes in various parts of the Madras Presidency.

The *third group* is even more interesting than the former two. The specimens are characterised by the most unusual occurrence of micrographic quartz in a pyroxene-plagioclase rock, and this character is constant, not only in various lava-flows, but in a large number of the dykes, which break through the crystalline rocks of South India, and which, from their peculiar distribution have long been suspected as the underground representatives of the Kadapah lava-flows. Whilst fully recognising the unsatisfactory nature of correlation by unsupported petrological characters, it seems likely that we have in this little-suspected form of evidence further reasons for dividing the great thickness of the Kadapah system, and separating a lower portion to be regarded as contemporaneous with the Gwalior system of the North.

It is a curious fact that in precisely similar rocks occurring as sheets in the slates of Naini Tal there is the same occurrence of micrographic quartz; but our facts so far are by no means sufficient to make any attempt at correlating the

unfossiliferous rocks of the Himalayas with the great azoic systems of Peninsular India.

Besides the interest which rocks so exceptional in petrological character naturally create, the identification of the lava-flows with their underground dyke-representatives enables us to distinguish three distinct petrographical provinces, each of very ancient date, and it is the recognition of the peculiarities of contemporaneous, but widely-separated, volcanic outbursts that affords evidence in stratigraphical correlation which, in the absence of fossil remains, is by no means to be despised.

2. *Massive Minerals.*—Professor JUDD, C.B., F.R.S., has published two interesting papers in the *Mineralogical Magazine* (Vol. XI, pp. 49 and 56, 1895), in which he has described the mineralogical characters of the massive corundum and fibrolite-rock found in Mysore by Mr. Holland, and the well-known purple corundum deposit of South Rewah described by Mr. Mallet (*Records*, Vols. V and VI). The same distinguished author has also described in the same paper a peculiar fibrous schorl-rock, which was obtained by Mr. Bosworth-Smith in the Kolar gold-field and in the auriferous areas of Chota Nagpore. Large quantities of this rock have been collected by Mr. Anderson during his recent survey of the gold-bearing tracts of Chota Nagpore.

C. L. GRIESBACH,
Director, Geological Survey of India.

CALCUTTA;
1st May 1896.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1896. August.

On some Igneous Rocks *from the* Tochi Valley: *by* H. H. HAYDEN, B. E., *Assistant Superintendent, Geological Survey of India.*

The specimens about to be described form part of a collection made in Waziristan by Mr. Smith, of the Geological Survey of India. They are, to a great extent, derived from dykes and intrusions occurring among the tertiary beds of the Tochi Valley,[1] and represent a very fine series of varying texture and basicity, ranging from a compact and glassy prophyrite, through trachyte, basalt, dolerite and gabbro to serpentine and bronzitite.

They have all undergone a considerable amount of alteration, which is particularly noticeable in the gabbros, the felspar of which has in many cases become saussuritic, while the dolerites furnish examples of every stage in the conversion of augite into hornblende. Evidence of dynamo-metamorphic action, also, is abundant; the crushing and shearing of the serpentines, the foliation of some of the gabbros, with the brecciation of their constituent minerals, all bearing witness to the pressure to which these rocks have been subjected.

The specimens consist of two sets, *viz.*, (1) a series collected *in situ*, in the neighbourhood of the tertiary beds, and composed of igneous rocks, with baked and altered shales and fault-breccias, and (2) a number of specimens found in the bed of the Tochi river, being chiefly portions of rolled and waterworn pebbles of the above igneous rocks, with some mica-schist and altered limestone.

Serpentine.

Of the igneous rocks, the serpentines and gabbros are the most numerous, as well as the most varied in composition. As a rule, the serpentines are of a more or less uniform dark green colour; at times, however, they show spots of a translucent, very pale apple-green to greenish-white serpentine. Their hardness varies from $3\frac{1}{2}$ to $4\frac{1}{2}$, and their specific gravity from 2·49 to 2·76, this latter value being given by a specimen with many of the light spots already mentioned.

Microscopic characters. Serpentine.

Under the microscope, the serpentine is seen to vary considerably, some portions showing the mesh-structure characteristic of olivine, while others may be seen to have arisen from the alteration of pyroxene and amphibole. In some cases the rock has evidently undergone much pressure, the serpentine fibres being bent,

[1] See *Records, G. S. I.*, Vol. XXVIII., p. 109.

twisted and fringed at the ends, while in places they have been broken through and faulted, one part having been shifted past the other.

The serpentine varies from pale greenish-yellow to colourless, and is frequently intersected by clear bands of picrolite, which mineral may also be recognised on the outer surface of some of the hand-specimens.

Accessory minerals.

The chief accessory minerals found in these rocks include olivine, augite, enstatite, bastite, hornblende, and magnetite, the bastite at times occurring in large and brilliantly lustrous plates scattered throughout the rock. Several sections of an isotropic mineral, of a rich brown colour by transmitted light, represent chromite or picotite.

General characters.

The olivine is usually in an advanced stage of serpentinisation, being cracked and altered, while the cracks are filled with serpentine and dust-like magnetite. No. $\frac{10}{778}$. It has already been mentioned that one of the specimens has a higher specific gravity than the rest, *viz.*, 2·76. In the hand-specimen, the rock has a somewhat mottled appearance, consisting of a dark groundmass with large pale-green to greenish-white spots. The mineral of these spots is somewhat harder than the remainder of the rock, for it is found to scratch fluor spar, its hardness being therefore higher than degree 4.

Microscopic characters.
Serpentine.

Under the microscope, the rock is seen to consist almost entirely of serpentine, of which the greater part has been derived from olivine; a considerable quantity, however, has arisen from the alteration of enstatite.

Enstatite.

Some unaltered enstatite still remains, one large crystal being especially noticeable, owing to the fact that it polarises in patches of blue and grey: this effect is evidently due to brecciation, the crystal affording evidence of having been broken up, for veins of serpentine run through it, while portions of the enstatite may be seen scattered, in the forms of strings and veins throughout the surrounding serpentine.

Augite.

A few large crystals of a green augite may be seen, while a considerable quantity of amphibole is also present. Of the latter mineral there are two varieties, both of which are monoclinic. Of these, the first is a common brown hornblende, with fairly strong pleochroism. The second variety

Amphibole.

occurs in strings and small isolated, but broken crystals. It is highly pleochroic, the colours ranging through violet, greenish-blue and blue to greenish-yellow, and in some cases pale yellow. No cross-sections with well-defined outlines could be detected; a few imperfect cross-sections of the prism, however, occur. In these, the cleavage cracks parallel to (110) intersect at angles of 123°½ to 124°½. Vertical sections also occur giving very low extinction angles, *viz.*, 4°½—6°. The above characters point to the fact that this mineral is glaucophane, the pleochroism strongly resembling that of glaucophane, as figured by Teall in his "British Petrography,"[1] rays vibrating parallel to α giving yellow to greenish-yellow, those parallel to β violet and those parallel to γ blue.

Magnetite.

Magnetite is almost entirely absent, a very few small grains occurring in the hornblende.

[1] See J. J. Harris Teall, British Petrography, Pl. XLVII, fig. 2.

Gabbro.—The gabbros are as well represented as the serpentines, but are considerably more varied in composition, the forms without olivine being the most numerous. Olivine-gabbros, however, also occur, and include a very good specimen of "forellenstein," the troktolite of von Lasaulx.[1] This specimen was found in the bed of the Tochi river, and is a portion of a rolled pebble. A rock of very similar composition, however, occurs *in situ* between Dotoi and Sheranni. The specimen from the Tochi river—No. $\frac{10}{811}$—is composed of a bluish-grey felspar, in which are set the numerous dark, rounded patches of olivine. Its specific gravity is rather low, being only 2·80: this however, is due to the fact that the rock has undergone very considerable alteration.

Troktolite.

Under the microscope, it is seen to be composed chiefly of plagioclase and olivine, the remaining minerals being either of secondary origin or very subordinate in quantity. These include enstatite, augite, diallage, hornblende, bastite, epidote, serpentine and magnetite.

Microscopic characters.

The plagioclase occurs in large irregular rounded crystals, giving clear sections and broad lamellar twins. Referred to the plane of composition, the twin-lamellæ give extinction angles of 49° and upwards, while sections showing either basal or brachy-pinacoidal cleavage give high angles of 37° and 38°. These characters indicate that the felspar is anorthite.

Felspar.

As a rule, this anorthite is fairly fresh, except in the neighbourhood of the olivine crystals. Where it surrounds that mineral, it is penerated by a series of branching fissures, radiating from the olivine crystals and filled with decomposition products.[2] In other cases, however, it has a tendency to become saussuritic, with the development of grains and strings of epidote.

The olivine occurs in large crystals, either colourless or brownish-yellow, and may be seen in many stages of alteration. In some cases it is fairly fresh, being merely intersected by cracks filled with serpentine and dusty magnetite; in the majority of cases, however, it is considerably altered. This alteration takes chiefly three different forms:

Olivine.

1. Into serpentine.

2. The olivine crystal has become to a great extent converted into a felt of fine hornblende needles, with some serpentine and magnetite = *pilite* (Becke).

3. All except the centre of the crystal has been converted into hornblende and magnetite. In this case, however, we do not find the typical reaction zones between the olivine and the felspar; the usual colourless inner zone being entirely absent, while the hornblende is a confused mass of plates and fibres surrounding and penetrating the still unaltered portion of the olivine crystal, and even scattered through the neighbouring felspar. In cases of still further alteration, almost, if not quite the entire crystal of olivine has disappeared, and been replaced by a brecciated mass of hornblende fragments. This hornblende is often colourless in section, but is at times of a very pale green colour, in which case it is slightly pleochroic. It would therefore appear from the above facts, that the customary reaction zones had originally formed round the olivine, where that mineral adjoined the felspar; the rock then underwent dynamo-metamorphism,—a fact which is also borne witness to

[1] Von Lasaulx: Elemente der Petrographie, p. 315.

[2] See Judd. On the gabbros, dolerites and basalts of tertiary age in Scotland and Ireland. *Quart. Journ. Geol. Soc.*, Feb. 1886, Vol. XLII, p. 86, and Plate VII, fig. 7.

by the traces of foliation in the hand specimen—, the zones thus becoming broken up into a confused breccia of hornblende with some felspar fragments. In other cases, the synthetic twinning of the hornblende also gives evidence of the pressure that the rock has undergone.

Augite.

The remaining minerals in the rock include a pale green augite, which is highly ophitic, in some cases extinguishing simultaneously throughout the whole slide.

Rhombic pyroxene.

Secondary minerals.

A considerable quantity of enstatite is also present and may often be seen passing into bastite, while epidote, calcite and magnetite are among the secondary minerals, the last-named however, being in a few cases apparently one of the original constituents.

A very similar result of the great pressure to which all these rocks have been subjected, is strikingly illustrated by a specimen of gabbro (No. $\frac{10}{817}$) from the Tochi river. This rock appears to have been originally composed of plagioclase and augite : the augite is now represented by diallage, very highly schillerized and invariably surrounded by a zone of highly pleochroic green hornblende, which mineral has in many cases replaced the greater part of the diallage. This hornblende has again been broken up into a mosaic of pleochroic fragments, and is often to be seen intermingled with the felspar, and containing a considerable quantity of magnetite.

Gabbro without olivine.

The olivine-free gabbros are very numerous and occur in many stages of alteration. The majority, however, are much altered, the felspar having become saussuritic. This saussurite is chiefly of two kinds: (1) an indistinct, greyish mass, containing and often to a great extent composed of grains and, at times, large crystals of zoisite—No. $\frac{10}{814}$— and (2) a clear groundmass of albite in which are scattered numerous grains and long prismatic crystals of epidote—No. $\frac{10}{818}$—; a form of alteration first recognised by Cathrein.[1] The diallage also has to a great extent passed into a green hornblende, which usually shows the effect of metamorphism.

Felspar.

The freshest specimen—No. $\frac{10}{812}$— is part of a pebble from the Tochi river-bed, and contains felspar, enstatite, diallage, hornblende, magnetite and some epidote. The felspar, which is labradorite, is wonderfully fresh, only in a few cases showing signs of the formation of epidote.

Diallage.

Hornblende.

The diallage occurs in large quantity and is usually surrounded by an alteration-zone of hornblende, or else entirely converted into that mineral. The hornblende is both uralitic and actinolitic, the pleochroism of the latter giving green, brownish-green and bluish. Fibres may also be seen running along the cracks and twinning planes of the felspar. A considerable quantity of magnetite occurs in the hornblende.

Magnetite.

Under the microscope, this rock very strongly resembles the hornblende-gabbro of Crousa Down in Cornwall, figured by Teall in his "British Petrography," Pl. XVIII, fig. 2.

[1] Cathrein. Ueber Saussurit. *Zeitschr für Kryst.*, 1883, Bd. VII, 234, also Teall, British Petrography, p. 149 *et seq.*

Altered gabbro with glaucophane.

Of the remaining gabbros, only one calls for special mention. This rock —No. $\frac{10}{818}$ — consists of pseudomorphs after felspar, and large quantities of monoclinic pyroxene (augite and diallage), with their alteration-products. The chief interest of the rock centres in the pyroxene. Under the microscope it is seen to be considerably altered; in a few places being converted into patches of brown hornblende; in most cases, however, the crystals are surrounded by a border of a clear blue mineral, which also runs along the cracks in the pyroxene and occurs in rods and patches in the neighbourhood of that mineral. It is highly pleochroic, giving violet, pale yellow and a clear sky-blue. On vertical sections, the angle of extinction is very small, not rising above 3° or 4°. This mineral is therefore glaucophane, and as in the gabbros of Attica,[1] is, together with the brown hornblende, an alteration-product of the diallage.

Pyroxene.

Glaucophane.

Dolerite.—In the hand-specimens, the dolerites appear fairly compact, and are of a greenish-grey colour, with a specific gravity ranging from 2·84 to 2·87.

They are chiefly composed of plagioclase and augite with their respective alteration products. They are, in all cases, much altered, and contain numerous secondary minerals, such as epidote, leucoxene, calcite, etc., with much micropegmatite, and at times appear under the microscope to be merely a mass of decomposition-products.

Constituent minerals.

The least altered of these rocks—No. $\frac{10}{800}$ — consists of a triclinic felspar, augite, enstatite, hornblende, apatite, magnetite and ilmenite.

Felspar.

The felspar is much altered and often converted into saussurite with the development of epidote. It shows, however, the broad lamellar twinning characteristic of labradorite.

Augite.

The augite is usually pale green; but in the least altered specimen a considerable quantity of colourless augite occurs in the form of small crystals and fragments, frequently twinned, but it is more often to be seen passing into hornblende or into pale green structureless *viridite*, with no apparent cleavage, but which ultimately passes into uralite or into chlorite.[2]

Ilmenite.

Ilmenite occurs in considerable quantity, some of the crystals showing signs of alteration into leucoxene.

Altered dolerite.

Two other specimens, *viz.*, No. $\frac{10}{778}$ from Dotoi, and No. $\frac{10}{794}$ from Insar Kach, may very possibly be further stages in the alteration of the above rock. In the first, the whole of the augite has passed into viridite, and into a highly coloured brown hornblende, which surrounds, or occasionally occurs in patches in, the viridite, this latter passing into hornblende, and both being intimately connected with one another. As in the gabbros, signs of considerable dynamo-metamorphic action may be seen in this specimen, the hornblende being crushed and squeezed out into acicular rods and often scattered through the felspar. The large quantity of this mineral is very striking, and were

[1] See Zirkel. Lehrbuch der Petrographie. 1894. Bd. III, p. 787; also Bd. I, p. 310.

[2] See Judd. *loc. cit.*, p. 85.

it not for the presence of labradorite in place of oligoclase, the rock might be more properly classed as a diorite.

Epidote.

Leucoxene.

Much epidote occurs in the felspar, which is rapidly becoming saussuritic and times schillerized.

Leucoxene and sphene also occur, no unaltered ilmenite remaining.

Basalt.—The volcanic type of the basic rocks is represented by a specimen of amygdaloidal basalt—No. $\frac{10}{518}$ —which was found in the bed of the Tochi river. In the hand-specimen this rock shows white amygdaloids of calcite and zeolites, while a considerable quantity of porphyritic augite occurs. The ground-

Microscopic characters.

mass consists of innumerable small crystals of augite and apatite, with magnetite, decomposed plagioclase and brown glass. The augite, however, is by far the most important constituent. On rotation of the polariser, the rock is also seen to contain numerous flakes and fibres of a brown pleochroic mineral, which, under a high power, proves to be a dark mica; it occurs in flakes, as a rule without well-defined outlines. In addition to the above minerals, some secondary hornblende occurs, arising from the alteration of the augite.

The amygdaloidal cavities contain calcite and a zeolite, and their form indicates that these minerals are pseudomorphs after olivine and felspar, of which the original outlines have been retained. In one case, even the cleavage of the olivine appears to have been preserved, although that mineral has been replaced by calcite. All the porphyritic felspars and olivines, however, have been replaced, the only remaining felspar being the small decomposed crystals in the groundmass.

The augite is of the usual type, being frequently twinned and beautifully zoned.

Trachyte.—No. $\frac{10}{708}$.—This is a compact light bluish-grey rock, with a specific gravity of 2·60. It was obtained from a spot one mile to the west of Pakki Kot, and is of subsequent date to the accompanying shales, into which it has been intruded, and which are burnt and altered at the junction. In the hand-specimen, it appears to consist of a grey lithoidal groundmass, through which are scattered numerous small white crystals of felspar, some occurring in groups of small individuals, while other larger crystals occur singly.

Under the microscope, the rock is seen to be composed of a fine microscopic groundmass of felspar microlities, in which are embedded porphyritic crystals of plagioclase and sanidine. The plagioclases are much the smaller, and occur as

Plagioclase.

a rule in groups, the crystals showing broad lamellar twinning. They are considerably altered, thus constrasting with the beautifully clear pellucid crystals of sanidine, which have idiomorphic outlines

Sanidine.

and are quite fresh, with but few inclusions. No ferro-magnesian minerals can be detected, the rock being composed merely of felspar with a large quantity of magnetite.

The remaining igneous rocks include specimens of porphyrite, diabase, bronzitite, bronzite-hypersthene rock and a rock composed

Bronzite-hypersthene rock.

of fibrous actinolite. The bronzite-hypersthene rock is composed of very large crystals of those minerals, some

of the individuals measuring as much as two inches across. This specimen comes from the hills to the north-west of Sheranni, while a specimen of bronzitite which is of finer texture, and is composed entirely of bronzite with some magnetite was found in the bed of the Tochi river.

Bronzite.

An interesting rock, also, comes from the river to the east of Dotoi. This is a heavy, green crystalline rock, of hardness = 5, or slightly higher, and a specific gravity of 3·25. It bears a strong resemblance, in the hand-specimen, to dunite, but under the microscope it is found to contain no olivine, while chemical analysis proves it to be composed chiefly of calamine ($H_2 Zn_2 Si O_5$), with smithsonite ($Zn Co_3$) and some zinc blende. A few cracks in the specimen have become filled with calcite. This rock bears a close resemblance to the massive calamine of Altenberg in Rhenish Prussia. It was apparently not obtained *in situ*, being rolled and waterworn.

Calamine-Smithsonite.

The remaining rocks include recent river breccias, also specimens of red and green jasper from the Tochi river, and a few metamorphic rocks, amongst which are garnetiferous mica-schist, calc-schist, and baked shales.

The baked shales occur in contact with the igneous rocks, and have been more or less fused; some have been much altered, showing signs of considerable fusion and having a hardness of 6 or more, while under the microscope they are seen to consist of a glassy groundmass, containing in places small crystals, which appear to be the product of recrystallisation.

Baked shale.

Notes from the Geological Survey of India.

Rewah.—Among the fossils from the lower Gondwanas collected during the past working season, is a clump of *Glossopters* fronds, attached to a portion of their root stock. The specimen is not so well preserved as might be wished, but the fronds are readily enough recognised and the fragment of root-stock shows the characters of *Vertebraria*. In the Comptes Rendus of this year M. R. Zeiller, under date 23rd March, described the discovery of *Glossopters* fronds attached to *Vertebraria* in the Transvaal, so the true nature of *Vertebraria*, long in doubt, may be taken to be settled as the root-stock of *Glossopters*. A figure and description of the Rewah specimen will be published.

Burma.—Mr. Hayden visited and examined the steatite mines supposed to be in the Minbu district, but really situated to the west of the Yoma in the Kyakpyu district of Arakan. The steatite occurs in thin bands and lenticular patches in the serpentine intrusions of the Arakan Yoma and is of great purity.

Kelat.—A collection of fossils from the hills near Kelat has been made by Lala Kishen Sing. The fossils have not yet been examined, but the discovery of *Orthocerus* by Dr. Carter (see Manual, 2nd edition, page 143) does not seem to have

been repeated. The most interesting stratigraphical fact to record is the direct contact of uppermost nummulitic (Spintangi) beds with the massive (jurassic) limestone, which had in one place been eroded till only 15 to 20 feet remained out of 300 feet seen close by.

R. D. OLDHAM.

DONATIONS TO THE MUSEUM.

FROM 1ST MAY TO 31ST JULY 1896.

Native Gold, with pyrites, in quartz, from the Chowkpazat Gold Mine, Wuntho, Burma
PRESENTED BY C. M. P. WRIGHT.

Specimens of pegmatite; muscovite with schorl; and biotite and muscovite in parallel crystals, from Bendee, Hazaribagh district, Bengal.
PRESENTED BY A. GOW SMITH.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1896.

Titles of Books. *Donors.*

BOECK, *K.*—Himalaya album. 4° Baden-Baden, 1894.

BRONN, *H. G.*—Klassen und Ordnungen des Thier—Reichs. Band II, Abth. II, lief. 11—14, and Band IV, lief. 43—44. 8° Leipzig, 1896.

BROWN, *C. B., and* JUDD, *J. W.*—The rubies of Burma and associated minerals; their mode of occurrence, origin and metamorphoses. A contribution to the history of Corundum. 4° London, 1896.
REV. AND AGRI. DEPT.

CARRARO, *Antonio*—Reale Istituto Veneto di Scienze, Lettre ed Arti. Indice Generale dei Lavori Publicati, 1840-41, Al 1893-94. Vols. I—II. 8° Venezia, 1896.

COTTEAU, *G.*, GAUTHIER, *V.*, *and* DOUVILLE, *H.*—Paleontologie de la Mission Scientifique en Perse. 4° Paris, 1895.

COX, *W. G.*—Artesian Wells as a means of water supply. 8° Brisbane, 1895.

DE CHERVILLE, *G.*—Les Éléphants État Sauvage Domestication. 8° Paris.

DE GREGORIO, *A.*—Coralli del Terziario di Sicilia. 4° P. Palermo, 1894.
THE AUTHOR.

" Nuovi Strumenti Fisici e Metereologici. 4° Palermo, 1893.
THE AUTHOR.

FOCK, *Andreas.*—An introduction to chemical crystallography. Translated and edited by W. J. Pope. 8° Oxford, 1895.

FRIDRICI, *C.*—Apercu Geologique du Department de la Moselle. 8° P. Paris, 1862.
THE AUTHOR.

FUGGER, *E.*—Beobachtungen in den Eishöhlen des Untersberges bei Salzburg. 8° Salzburg, 1888.

" Eishöhlen und Windröhren. 8° Salzburg, 1891—1893.

GRATELOUP.—Notice Geognostique sur les Roches du Bassin de L'Adour. 8° Bordeaux, 1845.
THE AUTHOR.

HARKER, *Alfred.*—Petrology for Students; an introduction to the study of rocks under the microscope. 8° Cambridge, 1895.

HATCH, *F. H., and* CHALMERS, *J. A.*—The Gold Mines of the Rand. 8° London, 1895.

HILGARD, *E. W.*—Alkali Lands, Irrigation and Drainage in their mutual relations. 8° P. Sacramento, 1892.
THE UNIVERSITY OF CALIFORNIA.

KUNZ, *George F.*—Precious Stones. 8° P. Washington, 1893.
U. S. GEOL. SURVEY.

Titles of Books.	*Donors.*
KUNTZE, *Dr. Otto.*—Geogenetische Beiträge. 8° Leipzig, 1895.	
LYMAN, *B. S.*—Folds and Faults in Pennsylvania Anthracite—Beds. 8° P. Philadelphia, 1895.	THE AUTHOR.
„ Report on the New Red of Bucks and Montgomery Counties. 8° P. Philadelphia, 1895.	THE AUTHOR.
McMAHON, *C. A.*—Some Structural Characteristics of the Granite of the North-Western Himalayas. 8° P. London, 1896.	THE AUTHOR.
MOJSISOVICS, *Dr. E. V., and* NEUMAYR, *Professor Dr. M.*—Beiträge zur Paläontologie und geologie österreich—ungarns und des orients. Band IX, heft. 1—4, and X, heft. 1—2. 4° Wien and Leipzig, 1896.	
MURRAY, *J. A. H.*—A new English Dictionary on Historical Principles. Vol. III. (Development—Diffluency). 4° Oxford, 1896.	
POSEPNY, *F.*—Archiv für Practische Géologie. Band I. 8° Wien, 1880.	
PREISWERK, *Gustav.*—Beiträge zur Kenntniss der Schmelzstructur bei Säugethieren. 8° Basel, 1895.	
RECLUS, *Elisée.*—Nouvelle Géographie Universelle la Terre et les Hommes. Vol. IX. 8° Paris, 1884.	
REDWOOD, *Boverton, and* HOLLOWAY, *G. T.*—Petroleum and its Products. Vols. I—II. 8° London, 1896.	
REEVE, *L. A.*—Conchologia Iconica: or illustrations of the shells of Molluscous Animals Continued by G. B. Sowerby. Vols. I—XX. 4° London, 1843—1878.	
RICHARDS, *Joseph W.*—Aluminium: its history, occurrence, properties, metallurgy and application, including its alloys. 8° London, 1896.	
ROYAL SOCIETY Catalogue of Scientfic Papers. Vol. XI. 4° London, 1896.	
SIMONY, *F.*—Das Dachsteingebiet. Vol. III. 4° Wien, 1895.	
TOULA, *Frans.*—Neuere Erfahrungen über den geognostischen Aufbau der Erdoberfläche. No. IV. 8° Wien, 1890—1892.	THE AUTHOR.
„ Der Jura im Balkan Nördlich von Sofia. 8° Wien, 1893.	THE AUTHOR.
„ Streiflichter auf die jungste epoche der Cultur. 8° P. Wien, 1893.	THE AUTHOR.
TRYON, *G. W.*—Manual of Conchology. Series I, part 62; and II, part 38. 8° Philadelphia, 1896.	
WALCOTT, *C. D.*—Note on some appendages of the Trilobites. 8° P. Washington, 1894.	THE AUTHOR.
WATTS, *W. L.*—The Gas and Petroleum yielding formations of the Central Valley of California. 8° P. Sacramento, 1894.	CALIFORNIA STATE MINING BUREAU.
ZEILLER, *M. R.*—Note sur la Flore Fossile des Gisements Houillers de Rio Grande Do Sul (Brésil Méridional). 8° P. Paris, 1895.	THE AUTHOR.
„ Sur l'attribution du genre Vertebraria. 4° P. Paris, 1896.	THE AUTHOR.

PERIODICALS, SERIALS, ETC.

American Geologist. Vol. XVII, Nos. 3—6, 8° Minneapolis, 1896.	
American Journal of Science. Series IV, Vol. I, Nos. 4—6. 8° New Haven, 1896.	THE EDITOR.

Titles of Books. *Donors.*

American Naturalist. Vol. XXX, Nos. 351—353. 8° Philadelphia, 1896.

Annalen der Physik und Chemie. Neue Folge, Band LVII, heft 3—5. 8° Leipzig, 1896.

Annales de Geologie et de Paléontologie. Livr. 19—20. 4° Palerme, 1896.

Annals and Magazine of Natural History. Vol. XVII, Nos. 100—102. 8° London, 1896.

Athenæum. Nos. 3569—3581. 4° London, 1896.

Beiblätter zu den Annalen der Physik und Chemie. Band XX, Nos. 3—5. 8° Leipzig, 1893.

Chemical News. Vol. LXXIII, Nos. 1895—1907. 8° London, 1896.

Colliery Guardian. Vol. LXXI, Nos. 1838—1850. Fol., London, 1896.

Geological Magazine. New series, Decade IV, Vol. III, Nos. 4—6. 8° London, 1896.

Glacialists' Magazine. Vol. III, pts. 1—2. 8° London, 1895.

Index of Authors and Subjects, Vols. I—X, of the Mineralogical Magazine. 8° London, 1896.

Industries and Iron. Vol. XX, Nos. 1210—1222. 4° London, 1896.

Journal of Geology. Vol. IV, Nos. 2—3. 8° Chicago, 1896.

London, Edinburgh and Dublin Philosophical Magazine. Vol. XLI, Nos. 251—253. 8° London, 1896.

Mining Journal. Vol. LXVI, Nos. 3160—3172. Fol., London, 1896.

Natural Science. Vol. II, No. 14, and VIII, Nos. 50—52. 8° London, 1893 and 1896.

Nature. Vol. LIII, Nos. 1377—1389. 8° London, 1896.

Palæontographica. Band XLIII, lief. 1—2. 4° Stuttgart, 1896.

Palæontologische Abhandlungen. Neue Folge, Band III, heft 2. 4° Jena, 1896.

Petermann's Geographischer Mittheilungen. Band XLII, Nos. 3—5. 4° Gotha, 1896.
THE EDITOR.

Scientific American. Vol. LXXIV, Nos. 10—22. Fol., New York, 1896.

" " Supplement. Vol. XLI, Nos. 1053—1065. Fol., New York, 1896.

The Indian and Eastern Engineer. Vol XXVI, Nos. 469—480. Fol., Calcutta. 1896.

Tschermak's Mineralogische und Petrographische Mittheilungen. Band XV, heft 5—6. 8° Wien, 1896.

Zeitschrift der Gesellschaft für Erdkunde zu Berlin. Band XXXI, Nos. 1—2. 8° Berlin, 1896.

Zeitschrift für Krystallographie und Mineralogie. Band XXVI, heft 1—3. 8° Leipzig, 1896.

Zeitschrift für praktische Geologie. Jahrgang 1896, heft 3—5. 4° Berlin, 1896.

GOVERNMENT SELECTIONS, REPORTS, ETC.

BOMBAY.—Selections from the Records of the Bombay Government. New series, Nos. 303, 305 and 343. Flsc., Bombay, 1895. BOMBAY GOVERNMENT.

BANGALORE.—Report on the administration of Coorg for 1894-95. Flsc., Bangalore, 1895. CHIEF COMMISSIONER, COORG.

INDIA.—Archæological Survey of India. Vol. II, part 3. 8° Madras, 1895.
GOVERNMENT OF INDIA.

" Government of India. Civil Budget Estimate for 1896-97. Flsc., Calcutta, 1896. GOVERNMENT OF INDIA.

Titles of Books. *Donors.*

INDIA.—Indian Meteorological Memoirs. Vol. IX, parts 4 and 5. 4° Calcutta, 1896.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

" Monthly Weather Review, October and November, 1895. 4° Calcutta, 1896.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

" List of Civil Officers holding Gazetted appointments under the Government of India, in the Home, Legislative, Foreign and Revenue and Agricultural Departments, corrected to 1st January 1896. 8° Calcutta, 1896.
GOVERNMENT OF INDIA.

" Report on the Administration of the Andaman and Nicobar Islands and the Penal Settlements of Port Blair and the Nicobars for 1894-95. Flsc. Calcutta, 1895. GOVERNMENT OF INDIA.

" Statistical Atlas of India. 2nd Edition. Fol., Calcutta, 1895.
REVENUE AND AGRICULTURAL DEPARTMENT.

MADRAS.—Annual Administration Report of the Forest Department, Madras Presidency, for the twelve months ending 30th June 1895. Flsc., Madras, 1896.
MADRAS GOVERNMENT.

" Appendix to the Report on the Government Central Museum, Madras. 8° P. Madras, 1856. MADRAS GOVERNMENT.

" Madras Observatory, Daily Meteorological Means. 4° Madras, 1896.
MADRAS GOVERNMENT.

PUNJAB.—Gazetteer of the Sialkot District, 1894-95. Revised Edition. 8° Lahore, 1895.
PUNJAB GOVERNMENT.

TRANSACTIONS, PROCEEDINGS, ETC., OF SOCIETIES, SURVEYS, ETC.

BALTIMORE.—Johns Hopkins University Circulars. Vol. XV, Nos. 123—124. 4° Baltimore, 1896. THE UNIVERSITY.

BATAVIA.—Naturkundig Tijdschrift voor Nederlandsch-Indië. Deel LV. 8° Batavia, 1896. THE SOCIETY.

BERKELEY.—Bulletin of the Department of Geology, University of California. Vol. I. Nos. 1—9. 8° Berkeley, 1893-95. THE UNIVERSITY.

BERLIN.—Verhandlungen der Gesellschaft für Erdkunde zu Berlin. Band XXIII, Nos. 2—3. 8° Berlin, 1896.

BOSTON.—Memoirs of the Boston Society of Natural History. Vol. V, Nos. 1—2. 4° Boston, 1895. THE SOCIETY.

" Proceedings of the Boston Society of Natural History. Vol. XXVI, pt. 4. 8° Boston, 1895. THE SOCIETY.

" Proceedings of the American Academy of Arts and Sciences. New series, Vol. XXII. 8° Boston, 1895. THE ACADEMY.

BRISBANE.—Proceedings of the Royal Society of Queensland. Vol. XI, pt. 2. 8° Brisbane, 1896. THE SOCIETY.

BRUXELLES.—Bulletin de la Société Royale Belge de Geographie. Anee XIX, No. 6. 8° Bruxelles, 1895. THE SOCIETY.

BUDAPEST.—Természetrajzi Füzetek. Vol. XIX, pt. 2. 8° Budapest, 1896.
HUGARIAN NATIONAL MUSEUM.

CALCUTTA.—Calcutta University Calender, 1896. 8° Calcutta, 1896.
THE UNIVERSITY.

Titles of Books. *Donors.*

CALCUTTA.—Geological Survey of India Department Quarterly Notes. No. 2. Flsc., Calcutta, 1896. GEOLOGICAL SURVEY OF INDIA.

„ Palæontologia Indica, Ser. XVI, Vol. I, pt. 1. 4° Calcutta, 1895. GEOLOGICAL SURVEY OF INDIA.

„ Records of the Geological Survey of India. Vol. XXIX, pt. 2. 8° Calcutta, 1896. GEOLOGICAL SURVEY OF INDIA.

„ Report on the Inspection of the Singareni Colliery, Yellandu, Hyderabad (Deccan). April 1895. By James Grundy. Flsc., Calcutta, 1895. GEOLOGICAL SURVEY OF INDIA.

„ Journal of the Asiatic Society of Bengal. Vol. LXIV, pt. I, No. 4, and pt. II; and LXV, pt. I, No. 1. 8° Calcutta, 1896. THE SOCIETY.

„ Proceedings of the Asiatic Society of Bengal. No. X (1895) and No. I (1896). 8° Calcutta, 1896. THE SOCIETY.

„ Proceedings and Journal of the Agricultural and Horticultural Society of India. Vol. X, January to March 1896. 8° Calcutta, 1896. THE SOCIETY.

„ Survey of India Department Notes for March to May 1896. Flsc., Calcutta and Simla, 1896. SURVEY OF INDIA DEPARTMENT.

CAMBRIDGE.—Proceedings of the Cambridge Philosophical Society. Vol. IX, pt. 2. 8° Cambridge, 1896. THE SOCIETY.

CAMBRIDGE, MASS.—Bulletin of the Museum of Comparative Zoology. Vol. XXVII, No. 7, and XXIX, No. 1. 4° Cambridge, Mass., 1896. THE MUSEUM.

CASSEL.—Abhandlungen und Bericht des Vereins für Naturkunde zu Kassel. No. XL. 8° Kassel, 1895. THE SOCIETY.

CINCINNATI.—Journal of the Cincinnati Society of Natural History. Vol. XVIII, Nos. 1—2. 8° Cincinnati, 1895. THE SOCIETY.

COPENHAGEN.—Oversigt over det Kongelige Danske Videnskabernes Selskabs Forhandlinger og dets Medlemmers Arbejder i Aaret, 1896. Nos. 1 and 2. 8° Kobenhavn, 1896. THE ACADEMY.

DES MOINES.—Iowa Geological Survey Vol. IV. 4° Des Moines, 1895. THE SURVEY.

DRESDEN.—Nachtrag zu dem Führer Durch Das Kgl. Mineralogisch Geologische und Praehistorische Museum in Dresden. 8° Dresden, 1893. THE MUSEUM.

„ Sitzungsberichte und Abhandlungen der Naturwissenschaftlichen Gesellschaft Isis in Dresden. Jahrgang, 1895, July to December. 8° Dresden, 1896. THE SOCIETY.

DUBLIN.—Proceedings of the Royal Irish Academy. 3rd series, Vol. III, No. 4, and List of Members for 1895. 8° Dublin, 1895. THE ACADEMY.

„ Transactions of the Royal Irish Academy. Vol. XXX, pts. 15—17. 4° Dublin, 1895. THE ACADEMY.

EDINBURGH.—Scottish Geographical Magazine. Vol. XII, Nos. 4—6. 8° Edinburgh, 1896. THE SOCIETY.

GOTTINGEN.—Nachrichten von der K. Gesells. der Wissens. zu Göttingen. Mathematisch-Physikalische Klasse. 1896, Heft 1; and Geschäftliche Mittheilungen. 1896, Heft 1. 8° Gottingen, 1896. THE SOCIETY.

Titles of Books. *Donors.*

LAUSANNE.—Bulletin de la Societe Vaudoise des Sciences Naturelles. Serie 3, Vol. XXXI, No. 118. 8° Lausanne, 1895. THE SOCIETY.

LEIPZIG.—Abhandlungen der Mathematisch-physischen classe der Konigl. Sachsischen Gesellschaft der Wissenschaften. Band XVIII—XX, XXII, XXIV, XXVI, XXVII, XXIX, XXXI, XXXIII, XXXV, XXXVIII; and XL, No. 1. 8° Leipzig, 1896. THE SOCIETY.

" Berichte Über die Verhändlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig; Mathematisch-Physische classe, 1870—1895, and 1896, No. 1. 8° Leipzig, 1870—1896. THE SOCIETY.

LIEGE.—Annales de la Societe Geologique de Belgique. Tome XXIII, livr. 1. 8° Liege, 1896. THE SOCIETY.

LISBON.—Communicacoes de Direccao dos Trabalhos Geologicos de Portugal. Tome III, fasc. 1. 8° Lisboa, 1895-96. GEOLOGICAL SURVEY OF PORTUGAL.

LIVERPOOL.—Proceedings of the Literary and Philosophical Society of Liverpool. Vols. XLIV—XLIX. 8° Liverpool, 1890—1895. THE SOCIETY.

LONDON.—An introduction to the study of Rocks. British Museum (Natural History), Mineral Dept. 8° London, 1895. (2 copies).

" Catalogue of Fossil Fishes. Part III. By A. S. Woodward. 8° London, 1895. BRITISH MUSEUM.

" Catalogue of the Mesozoic Plants. The Wealden Flora. Part II. By A. C. Seward. 8° London, 1895. BRITISH MUSEUM.

" Journal of the Chemical Society. Vols. LXIX, and LXX, Nos. 400—402. 8° London, 1896.

" Journal of the Iron and Steel Institute. Vol. XLVIII, No. 2. 8° London, 1895. THE INSTITUTE.

" Journal of the Society of Arts. Vol. XLIV, Nos. 2261—2273. 8° London, 1896. THE SOCIETY.

" Proceedings of the Royal Society. Vol. LIX, Nos. 353—354. 8° London, 1895. THE SOCIETY.

" Proceedings of the Zoological Society of London. Part 4. 8° London, 1896. THE SOCIETY.

" Transactions of the Zoological Society of London. Vol. XIV, pt. 1. 4° London, 1896. THE SOCIETY.

" Quarterly Journal of the Geological Society. Vol. LII, pt. 2, No. 206. 8° London, 1896. THE SOCIETY.

" Report on the British Association for the advancement of Science, 1895. 8° London, 1896.

" Geographical Journal. Vol. VII, Nos. 4—6. 8° London, 1896. THE SOCIETY.

" Royal Geographical Society. Notes of a Journey on the Upper Mekong, Siam, by H. W. Smith. 8° London, 1895. THE SOCIETY.

" Royal Geographical Society. The Topography of the Battle of Platæa, by G. B. Grundy. 8° London, 1894. THE SOCIETY.

" Supplementary Papers of the Royal Geographical Society of London. Vol. III. 8° London, 1893. THE SOCIETY.

Titles of Books. *Donors.*

MADRID.—Boletin de la Sociedad Geografica de Madrid. Tomo XXXVII, Nos. 10—12. 8° Madrid, 1896. THE SOCIETY.

MANCHESTER.—Memoirs and Proceedings of the Manchester Literary and Philosophical Society. 4th series, Vol. X, Nos. 1—3. 8° Manchester, 1896. THE SOCIETY.

„ Transactions of the Manchester Geological Society. Vol. XXIV, pts. 5—7. 8° Manchester, 1896. THE SOCIETY.

MEXICO.—Boletin del Instituto Geologico de Mexico. Nos. 1—2. 4° Mexico, 1895. THE INSTITUTE.

MILAN.—Atti della Societa Italiana di Scienze Naturali. Vol. XXXVI, fasc. 1. 8° Milano, 1896. THE SOCIETY.

MOSCOW.—Bulletin de la Société Imperiale des Naturalistes de Moscou. Anee, 1895 No. 4. 8° Moscou, 1896. THE SOCIETY.

MUNICH.—Sitzungsberichte der Mathematisch-Physikalischen classe der K. b. Akademie der Wissenschaften. Heft III of 1895. 8° München, 1896. THE ACADEMY.

NAPLES.—Rendiconto della R. Accademia delle Scienze, Fisiche E. Matematiche. Serie 3, Vol. II, fasc. 2—4. 8° Napoli, 1896. THE ACADEMY.

NEWCASTLE-UPON-TYNE.—Report of the Proceedings of the Flameless Explosives Committee of the North of England Institute of Mining and Mechanical Engineers. Part 3. 8° Newcastle-upon-Tyne, 1896. THE INSTITUTE.

„ Transactions of the North of England Institute of Mining, and Mechanical Engineers. Vol. XLIV, pt. 5, and XLV, pts. 1—2. 8° Newcastle-upon-Tyne, 1895-96. THE INSTITUTE.

„ Transactions of the Federated Institution of Mining Engineers. Vol X, pt. 3, and XI, pt. 1. 8° Newcastle-upon-Tyne, 1896. THE INSTITUTION.

NEW YORK.—Transactions of the New York Academy of Sciences. Vol. XIV. 8° New York, 1895. THE ACADEMY.

OTTAWA.—Summary Report of the Geological Survey Department for 18 5. 8° Ottawa, 1896. THE SURVEY.

PARIS.—Annales des Mines. Serié 9, Tome VIII, livr. 12, and IX, livr. 1—2. 8° Paris, 1895-96. DEPT. OF MINES, PARIS.

„ Bulletin de la Société Française de Mineralogie. Tome XIX, Nos. 2—4. 8° Paris, 1896.

„ Bulletin de la Société Gèologique de France. Serié 3, Tome XXIII, No. 7. 8° Paris, 1895. THE SOCIETY.

„ Memoires de la Société Géologique de France. Palèontologie. Tome V, fasc. 4. 4° Paris, 1895. THE SOCIETY.

„ Bulletin du Muséum d'Histoire Naturelle. 1896, No. 1. 8° Paris, 1896. THE MUSEUM.

Titles of Books. *Donors.*

PARIS.—Comptes Rendus des Séances de la Société de Géographie. Nos. 3—9. 8° Paris, 1896. THE SOCIETY.

PHILADELPHIA.—Journal of the Franklin Institute. Vol. CXLI, No. 844—845. 8° Philadelphia, 1896. THE INSTITUTE.

" Proceedings of the Academy of Natural Sciences. Pt. II. 8° Philadelphia, 1895. THE ACADEMY.

" Proceedings of the American Philosophical Society. Vol. XXXIV, No. 148. 8° Philadelphia, 1895. THE SOCIETY.

ROME.—Atti della Reale Accademia dei Lincei Rendiconti. Serie V, Sem. I, Vol. V. fasc. 5—10. 8° Roma, 1896. THE ACADEMY.

" Bolletino del R. Comitato Geologico d'Italia. Vol. XXVI, Nos. 1—4. 8° Roma, 1895. THE COMMISSION.

RIO DE JANEIRO.—Eclipses du soleil et occultations. 8° Rio de Janeiro, 1894. OBSERVATORY, RIO DE JENEIRO.

" Posições Geographicas. 4° Rio de Janeiro, 1895. OBSERVATORY, RIO DE JENEIRO.

SPRINGFIELD.—Bulletin of the Illinois State Museum of Natural History. No. 9. 8° Spring-field, 1896. THE MUSEUM.

STOCKHOLM.—Bihang Till Kongl. Svenska Vetenskaps Akademiens Handlingar. Band XX, pts. 1—4. 8° Stockholm, 1895. THE ACADEMY.

ST. PETERSBURG.—Materials for the Geology of Russia. Vols. I—XV. 8° St. Petersburg, 1869—1892. IMPERIAL MINERAL SOCIETY OF ST. PETERSBURG.

" Verhandlungen der Russisch-Kaiserlichen Mineralogischen Gesellschaft. Serie 2, Band XXXIII, lief. 1. 8° St. Petersburg, 1895. THE SOCIETY.

SYDNEY.—Proceedings of the Linnean Society of New South Wales. 2nd series, Vol. X, pt. 4. 8° Sydney, 1896. THE SOCIETY.

" Records of the Geological Survey of New South Wales. Vol. V, pt. 1. 4° Sydney, 1896. THE SURVEY.

TAIPING.—Perak Museum Notes, No. III. 8° Taiping, 1894. GOVERNMENT, PERAK.

TURIN.—Atti della R. Accademia delle Scienze di Torino. Vol. XXXI, disp. 1—2 and 4—5. 8° Torino, 1895-96. THE ACADEMY.

" Memorie della Reale Accademia delle Scienze di Torino. Serie 2, Tomo XLV. 4° Torino, 1896. THE ACADEMY.

VENICE.—Atti del R. Istituto Veneto di Scienze, Lettre ed Arti. Serie 7, Tomo LIV, disp. 3—6. 8° Venezia, 1895-96. THE INSTITUTE.

VIENNA.—Jahrbuch der K. K. Geologischen Reichsanstalt. Band XLV, heft 1. 8° Wien, 1895. THE INSTITUTE.

" Verhandlungen der K. K. Geologischen Reichsanstalt. Nos. 14—18 (1895), and Nos. 1—5 (1896). 8° Wien, 1895-1896. THE INSTITUTE.

Titles of Books. *Donors.*

WASHINGTON.—An account of the Smithsonian Institution; its Origin, History, Objects and Achievements. 8° Washington, 1895. THE INSTITUTION.

„ Bulletin of the U. S. Dept. of Agriculture, No. 8. 8° Washington, 1896. U. S. DEPT. OF AGRIC.

„ Smithsonian Contributions to Knowledge. No. 980. 4° Washington, 1895. THE INSTITUTION.

„ Smithsonian Miscellaneous Collections. No. 971-972. 8° Washington, 1895. THE INSTITUTION.

WELLINGTON.—Twenty-eighth and Twenty-ninth Annual Report of the Colonial Laboratory, Mines Dept., Newzealand. 8° P. Wellington, 1894-95. MINES DEPT., NEW ZEALAND.

YORK.—Yorkshire Philosophical Society. Annual Report for 1895. 8° York, 1896. THE SOCIETY.

MAPS.

VIENNA.—Geographische Abhandlungen. Band VI, heft 1. Alas. Ob. Wien, 1895.

G. I. C. P. O.—No. 69 D. G. Survey—23-7-96—620.

Photo-etching.

Survey of India Offices, Calcutta, May 1896.

C. S. Middlemiss.

Records, Vol. XXIX. Plate III

Photo-etching.

Survey of India Offices, Calcutta, May 1896

VIEW IN THE CHALK HILLS, SHEWING MAGNESITE VEINS.

C. S. Middlemiss

Photo-etching.

Survey of India Offices, Calcutta, May 1896.

VEINS OF MAGNESITE IN DUNITE.

C. S. Middlemiss.

Records, Vol XXIX. Plate IV.

Photoetching

Survey of India Offices, Calcutta, May 1896.

VEINS OF MAGNESITE IN DUNITE.

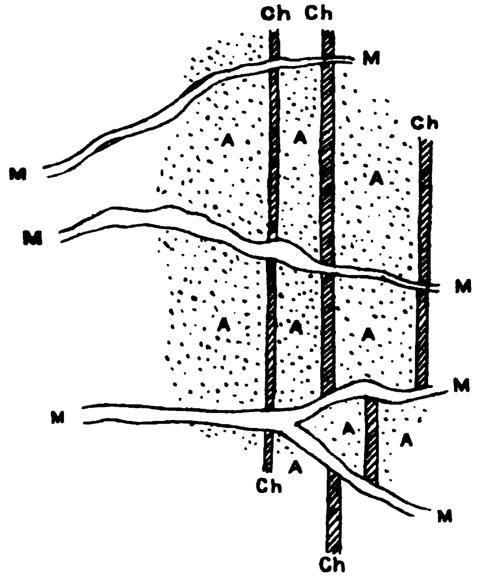
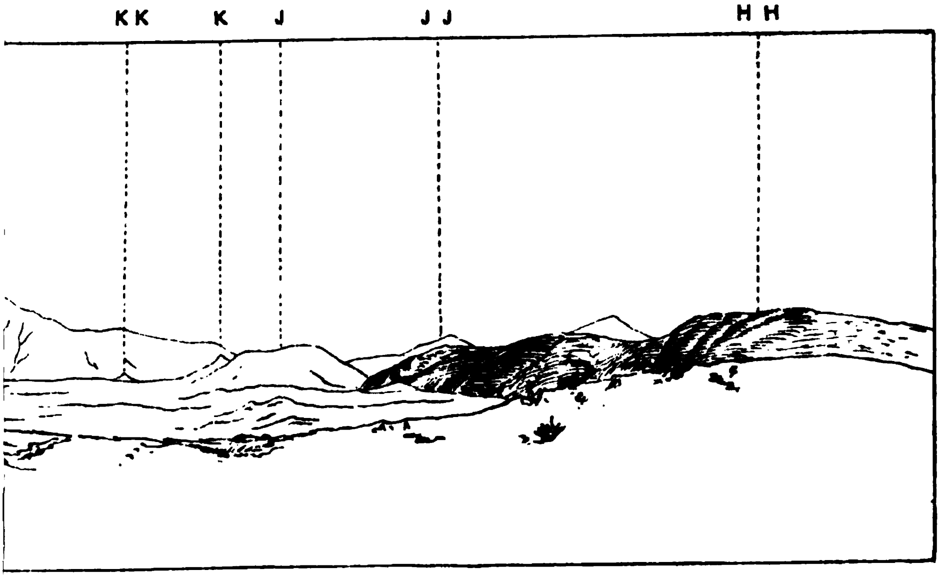


FIG. 1.

A = Serpentinised Dunite.
Ch = Veins of Chromite.
M = do.: Magnesite.

Scale

0 3 6 12 Inches



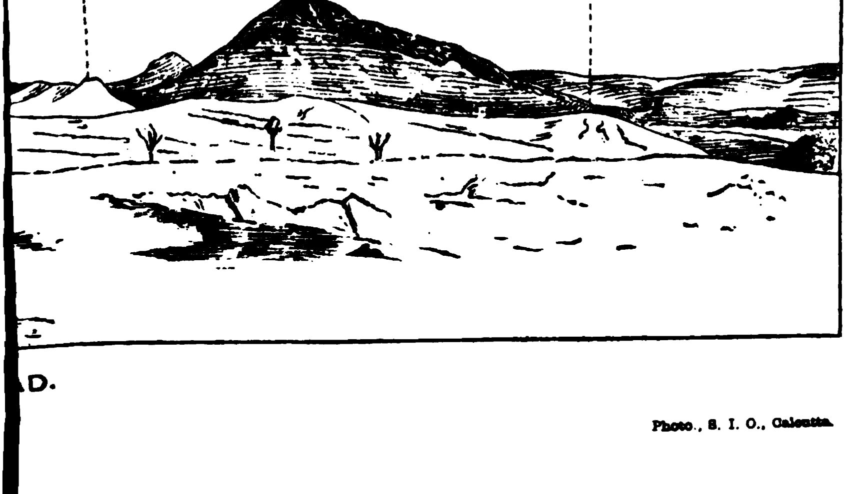


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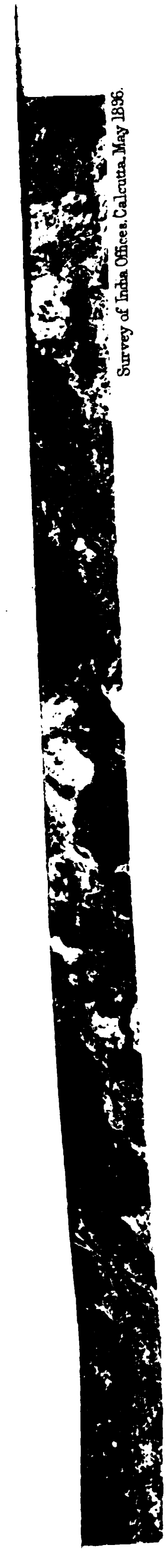
Photo., S. I. O., Calcutta.



Survey of India Offices, Calcutta, May 1896.

C S Middlemiss.

Photo-etching.

Survey of India Offices, Calcutta, May 1896.

VIEW IN THE CHALK HILLS, SHEWING MAGNESITE VEINS.

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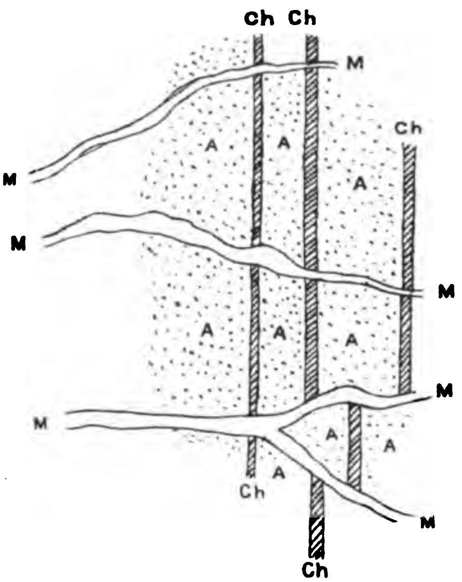
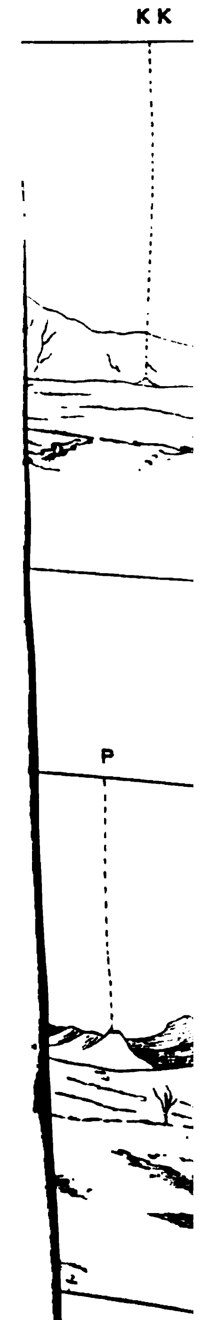


FIG. 1.

A = Serpentinised Dunite.
Ch = Veins of Chromite.
M = do.: Magnesite.

Scale


KK
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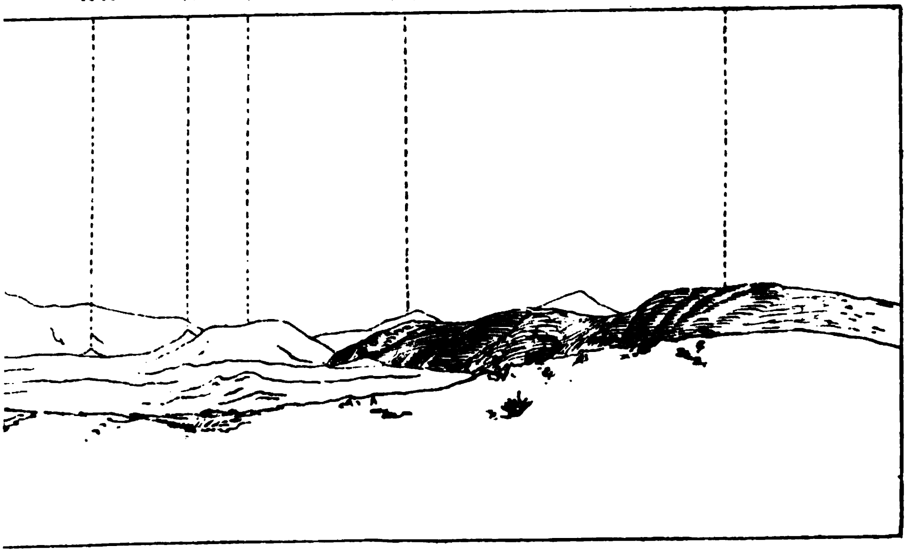

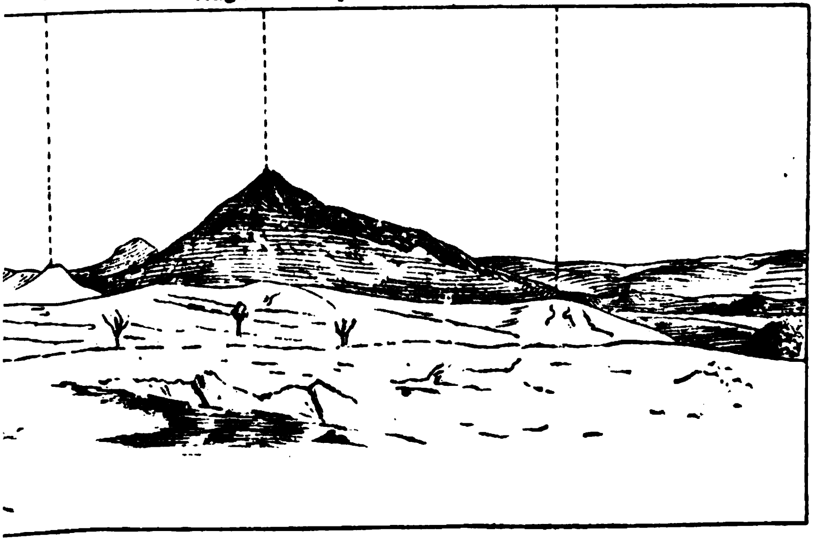

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Photo., S. I. O., Calcutta.

C. S. Middlemiss.

Records, Vol: XXIX. Pl. VII.

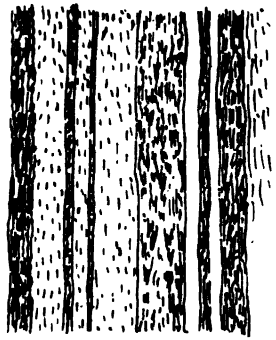


FIG. 1.

BANDED ANORTHITE HORNBLENDE GNEISS

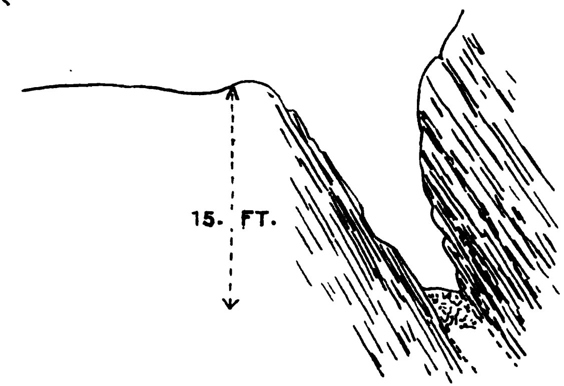


FIG. 2.

RED CORUNDUM MINE

(Section across)

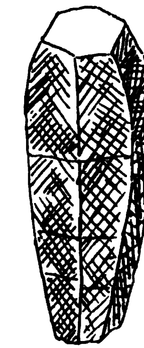
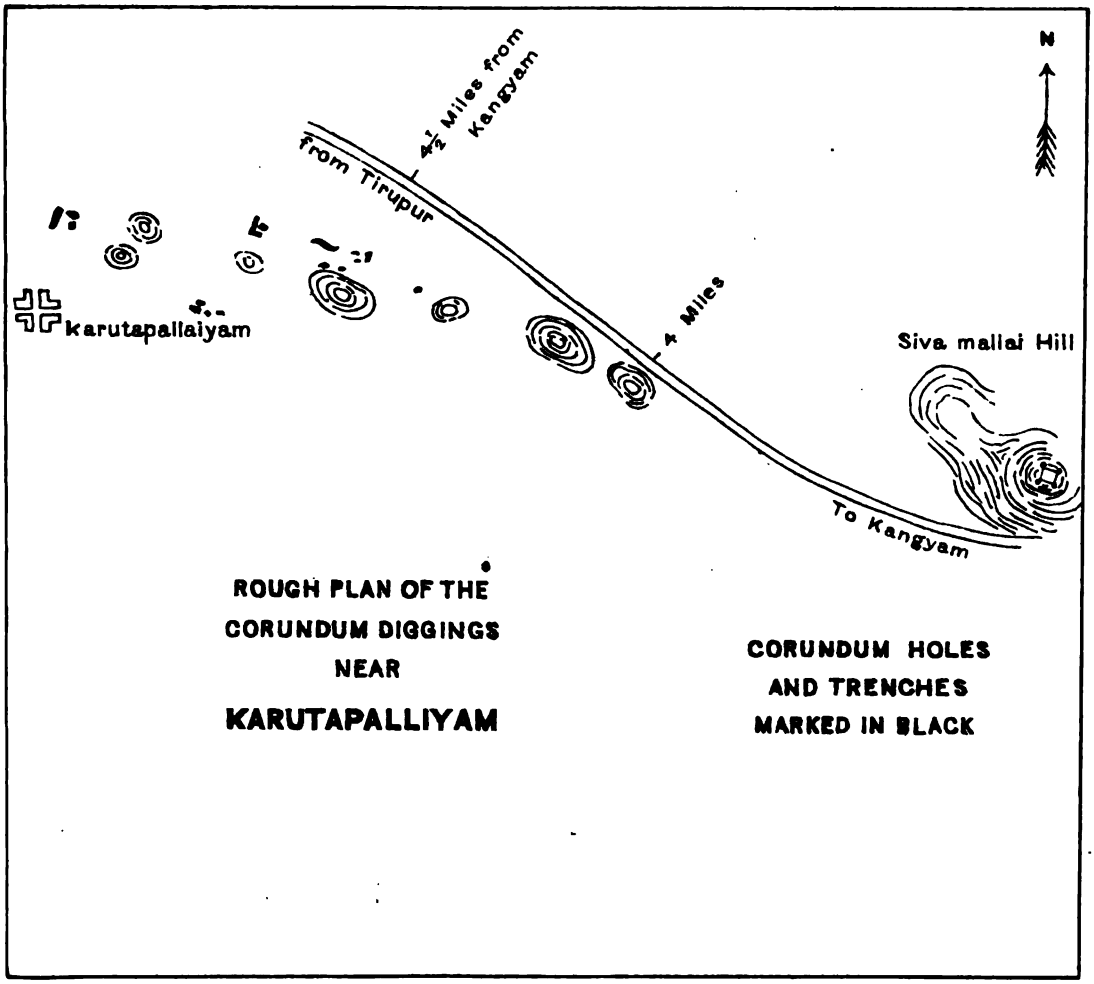


FIG. 3.

CRYSTAL OF OORUNDUM

C.S. Middlemiss.

Records, Vol: XXIX. Pl. VIII.



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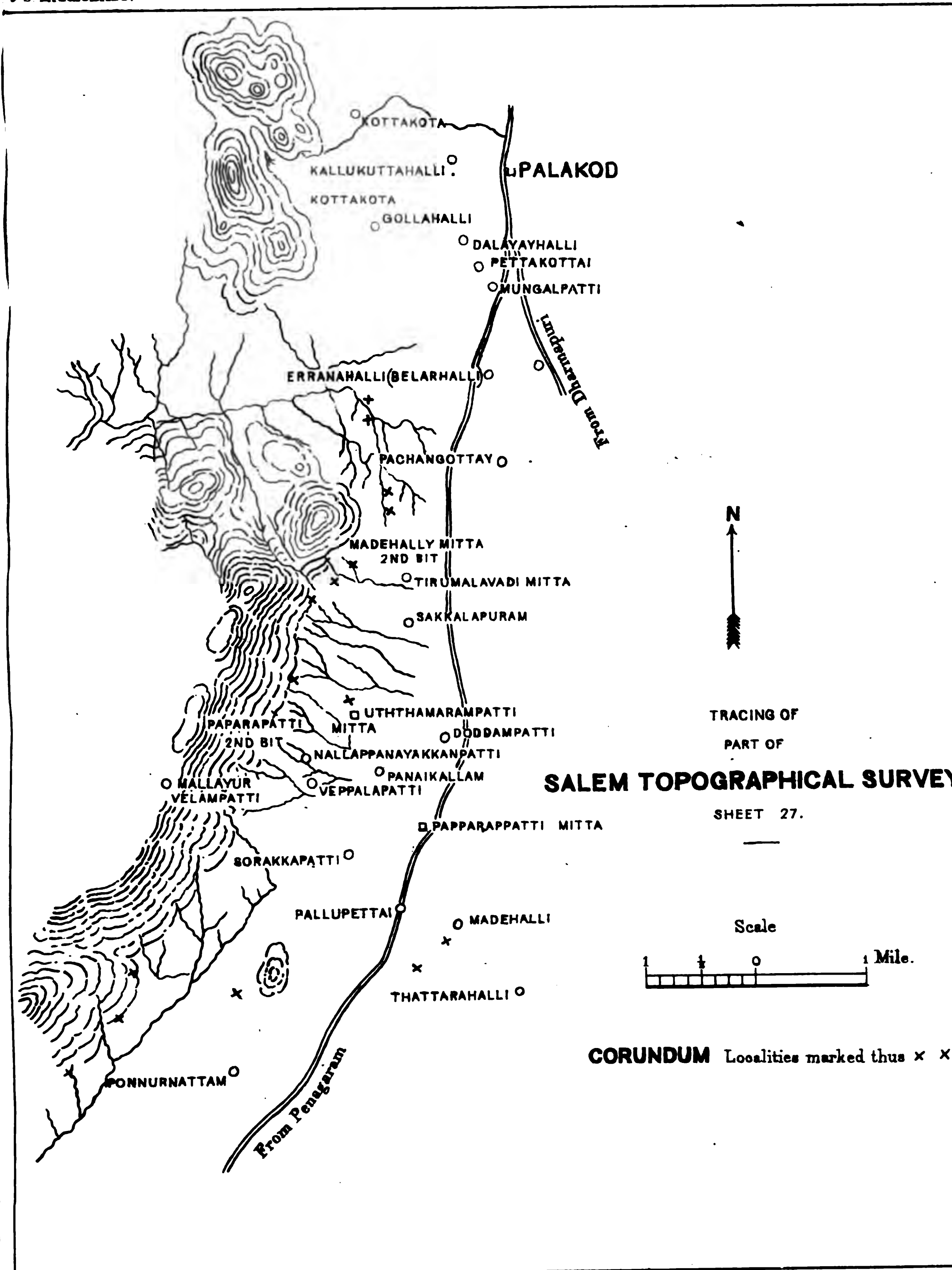

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1896. October.

Report *on the* Steatite mines, Minbu District, Burma, *by* H. H. HAYDEN, B.A., B.E., *Assistant Superintendent, Geological Survey of India.*

The two chief localities from which steatite is obtained in or near Minbu district are—

(1) the steatite mines some 30 miles west of the village of Hpa-aing; and

(2) the lately discovered mines near the village of Senlan in Ngapè township.

Steatite mines west of Hpa-aing.

Of these, the former are the older and the more important. They lie on the western side of the Arrakan Yoma, and, though supposed to be situated in Minbu district, are in reality some ten or fifteen miles over its western boundary[1]; they are, therefore, in the Kyaukpyu district of Lower Burma. Owing, however, to the erroneous impression prevailing as to the situation of the mines, and also to the fact that no information on the subject was obtainable in Minbu, I was unprovided with maps of Kyaukpyu district and can therefore indicate only the approximate position of the mines.

Accessibility.

The march from Hpa-aing occupies four days, the path running straight up and down the steep, jungle-clad sides of the Arrakan Yoma. The chief means of transport are pack bullocks. which carry loads ranging from ten to thirty viss[2]. The mountains, which are covered with dense jungle, are uninhabited, the last village—Thet-kai-kyin—being reached at the end of the first day's march from Hpa-aing, while the subsequent halting places are merely clearings in the jungle with no huts or other shelter.

History.

These mines have been worked for many years, having been in active operation before the annexation of the country by the British.

The mines.

Mining is carried on from October till the end of April or beginning of May, when work is abandoned on account of the rain.

The steatite occurs in veins traversing the dark green, intrusive serpentine, which is found in such large quantities in the Arrakan Yoma. This rock (serpentine) is

[1] One mine only, Hpo-gyi-dwin is situated in Minbu district. This is an old disused pit on the eastern slope of Hpo-gyi-taung.

[2] One viss = 3⅓ lb approximately.

in most cases found to contain steatite: frequently, however, merely in narrow ribbon-like veins. In places, these veins increase in thickness, attaining a width of eight or nine inches. When a band is found which is judged to be worth working a shaft is sunk along the vein and the steatite extracted till the vein is exhausted. During this process, other bands are frequently met with, and thus the shafts are found to ramify in all directions.

The total number of mines, including many not now in operation, amounts to about twenty-six. Of these only four were being worked at the time of my visit (May, 1896), and, owing to the fact that the rains had set in, work was abandoned soon after my arrival.

The four mines above mentioned were, however, fully examined, and may be described in the order in which they were visited.

(*a*) *Badwin.*—This mine is situated at about three miles south-west of Thit-myit-kyi, the halting place reached at the end of the third day's march from Hpa-aing. Two pits only are at present worked, but numerous old shafts, now either worked out or neglected, are seen in the neighbourhood. The present pits were unfortunately, at the time of my visit, unfit for descent owing to the large amount of rain which had already fallen: the sides and roof had already begun to fall, and consequently work had been abandoned. Considerable quantities of steatite, however, had been extracted and packed in baskets ready for removal. The steatite is of good quality and the miners say that the quantity still available is considerable.

(*b*) *Sambawgyi dwin.*—This mine is reached at the end the fourth day's journey, and is one of the most important. Here also only two pits are now worked, though the remains of nearly a dozen can be seen. Of these two pits, one had just become too unsafe to work, but the other (the better of the two) was still in operation, although, owing to the rain, much débris had already begun to fall. I succeeded, however, in descending and fully examining this shaft. The mining is of the most primitive type, and a short description may be of interest.

The mouth of the pit is nearly four feet square, and from this the shaft descends vertically to a depth of 56 feet. The sides are timbered for the first forty feet to prevent falls of rubbish. Below this depth the ground becomes firmer and through it the shaft is sunk vertically for 16 feet more; from this point, it slopes steeply in an easterly direction for 17 feet, then follows a vertical descent of 8 feet, after which the shaft slopes in a south-easterly direction, with numerous turns and steep descents, to a distance of 200 feet.

The size of the shaft is very variable, being at first nearly four feet square. After this, however, it narrows considerably and is usually only just large enough to allow of the passage of the miner, crawling on his hands and knees. In places, however, even this becomes impossible, and it is necessary to lie down and work one's body through narrow passages as much as ten feet or more in length. This is rendered even more unpleasant by the large quantity of water collected on the floor of the shaft, wherever it may chance to be level.

When, therefore, the rains have set in, and the roof and sides become soft and liable to fall, descent becomes a matter of extreme danger since a comparatively small fall of débris would completely block the passage. In addition to this, the entire absence of any form of ventilation is most trying. After descending to a

depth of some eighty feet or so the atmosphere becomes stifling and one experiences great difficulty in breathing. In fact, ventilation takes place solely by means of diffusion, which, in such narrow and tortuous passages, is a very slow and unsatisfactory process.

The steatite occurs in this shaft in two bands, seven and eight inches wide respectively. The mineral is fairly compact and of good quality, though in places it is crushed and useless.

(*c*) *Sambawgalé dwin.*—This mine is situated at about a quarter of a mile east of Sambawgyi. It also contains two shafts yielding good steatite.

(*d*) *Omyé dwin.*—This, though one of the oldest, is still the best mine now in operation. It is said to have been worked in the time of the last Burmese king, but has for some years been neglected, having only recently been re-opened. Only two pits are at present worked, and of these one had already been closed at the time of my visit, but the other was still in operation.

The shaft descends vertically for a depth of 45 feet, then branches into two narrow passages, running east and south-east respectively. Of these, the former descends steeply for ten feet, but work has been interrupted by the influx of water, which has necessitated the erection of pumping machinery; the other passage run for some fifteen feet to the south-east and contains a fine 9-inch band of steatite of great purity.

Extraction of the steatite.

The steatite is cut out from the surrounding serpentine by means of chisels. The broken pieces are then collected into small baskets and carried to the foot of the vertical shaft, whence they are drawn up to the surface by means of balance-poles.

Picking and cutting.

On reaching the surface the steatite is picked over, all worthless pieces being discarded. It is then sawn up into blocks of various sizes, chiefly into pieces of about 8" × 3" × 3" and into pencils ½ inch square in section and of varying length. The pieces are sorted and packed into panniers, and are then ready for removal.

2. The second set of mines is situated some 12 miles to the west of Shauktaung, (Shodan of map) in Ngapè township.

From Padein a fairly good cart track runs to Shauktaung, but from this latter village the remainder of the journey must be performed on foot.

From Shauktaung, a rough jungle path leads to a small Chin village named Won situated in the heart of the Arrakan Yoma and near the source of the Mankyaung. From Won a path runs to Senlan, a still smaller village, some 3½ miles further west. The steatite mines are situated at about 2 miles (by path nearly 5 miles) due west of Senlan on a steep mountain side overlooking the Mankyaung.

These mines were discovered a few months ago by some natives of Padein, who extracted a considerable amount of steatite before the matter was brought under the notice of the authorities.

There are nine pits in all, but of these several proved unproductive, only a few yielding sufficient steatite to be worth working.

These, however, have been carried down to at least 50 feet in depth, and probably considerably further. Owing, however, to the work having been interrupted, the pits have been deserted and descent is now impossible.

The steatite, which is of good quality, was extracted in large blocks, which in some cases attained a volume of half a cubic foot. These were sawn into smaller

pieces and into pencils, which were then buried beneath the floors of the miners' huts to be carried away as occasion offered. It is stated that when work was prohibited some 350 viss had already been removed: a large quantity, however, has been left behind and still remains in baskets buried beneath the huts.

Both the quantity and quality of the steatite here found point to the fact that the mines are worth working.

Value of the mines.

It has already been pointed out that the steatite occurs in veins in serpentine. In some cases the band of steatite rapidly dies out, but in others it may continue for several hundred feet. The steatite mining is therefore purely a matter of chance, for a vein may die out at any minute, and it is quite impossible to form any opinion as to the amount of steatite likely to be obtained from any given vein. It will, therefore, be evident that any statement as to the amount of this mineral available at the mines would be purely conjectural. All that can be said with any certainty is that the dark green serpentine appears to occur in very large quantities in the Arrakan Yoma, and where seen is usually found to contain steatite and that frequently in paying quantities, while the great purity of the mineral itself considerably enhances its value.

Geology.

The geology of Minbu district has already been described by Dr. Noetling in his paper on the "Development and Sub-division of the tertiary system in Burma[1]". From the map accompanying his paper, it will be seen that the upper tertiary rocks extend from Minbu to the foot of the Arrakan Yoma. Owing to the early date at which the rains set in on the Arrakan Yoma, I was forced to travel as rapidly as possible over this portion of the country, and was therefore unable to do more than remark the excellent exposures of tertiary rocks seen between Aingma and Ngapè, and the beautiful sections extending from Kyiwa to Mézali, along the banks of the Mon river, which cuts through the inclined tertiary strata, exposing an almost perfectly continuous section for many miles. Between Aingma and Ngapè are seen great beds of sandstone and clay. The sandstones contain many fossiliferous bands, which, though individually narrow, are both numerous and highly productive. As the road approaches Ngapè, the sandstones become unfossiliferous and between that place and Shauktaung, the beds appear to contain no recognisable organic remains. At about half a mile west of Shauktaung the sandstones are underlain by thick beds of very finely laminated dark shale with occasional carbonaceous bands. In these shales occur at first narrow bands of sandstone, and beneath these a thick bed of grey limestone, with nummulites in places: as a rule, however, in this neighbourhood, the limestones have been altered to such an extent by outbursts of a dark green serpentine, that the fossils are not recognisable. Beneath these limestones come—

(1) a bed of very dark purple schist, containing some limestone bands, and succeeded by

(2) an immense thickness of green and purple shales, containing enormous quantities of vein-quartz. These rocks (1 and 2) are presumably the "Chin shales" of Dr. Noetling.[2]

[1] Records G. S. I., Vol. XXVIII, Pt. 2, p. 59, sqq.

[2] Loc cit.

In the neighbourhood of Shauktáung, the tertiary beds dip to the east at an angle of 40°, and form parallel ranges of low hills running north and south and bordering the Arrakan Yoma. These rocks show no signs of alteration. As soon, however, as the "Chin shales" appear, a remarkable change is noticed: the rocks then become folded, crushed and faulted, and in this condition form the greater part of the Arrakan Yoma. At about 1½ mile west of Shauktaung the "Chin shales" first appear and continue without interruption to Won. About 1¼ mile west of Won they are well seen in the steep, precipitous sides of the Mankyaung. Here also occur numerous dykes and intrusions of a grey dolerite, which is seen in great masses in the "Chin shales". Numerous boulders of dark green serpentine and a somewhat fine grained green gabbro occur in the stream-bed. Two and a half miles west of Senlan are found large quantities of the above serpentine. The rock has been much crushed and in places strongly resembles the "Chin shales." It contains numerous veins of steatite, and it is here that the new mines already described have been opened.

The general strike of the rocks being north and south, the same beds are met with in the journey from Hpa-aing to the older quarries. A few points of difference are, however, noticeable. One of these is the much smaller quantity of vein-quartz found in the "Chin shales". Another very interesting feature of the rocks here is formed by numerous strings of quartzite pebbles and boulders enclosed in these shales: these enclosures are of all sizes and range from blocks weighing several tons down to fragments an inch or so in length. They appear to lie along the cleavage planes, with their long axes in the direction of strike of the cleavage. The enclosures are well seen in the Kyikyaung, at the halting place reached at the end of the third day's march from Hpa-aing. Here, too, a band of quartzite is seen interbedded with the shales. The appearance of the shales and their enclosures so exactly resembles that of the quartzite pebbles and boulders seen in the cambrian slates on the peninsula of Howth, near Dublin, that one is constrained to assume a similarity in their mode of origin.

This latter phenomenon has been described by Professor Sollas, who writes :— "...on the north side of Howth one may observe how great blocks of quartzite have been squeezed out from their bed during folding and carried into a stream of flowing slate, to form veritable intratelluric erratics. Near the nose of Howth whole trains of such erratics may be seen; these, no doubt, stand in connection with an important plane of shearing along the middle limb of an overfold....The whole terrane seems here to have been thrown into a state of intestine movement flowing up, down and sideways, and even whirling round about." [1]

The boulders of quartzite are in some cases so large as to preclude the probability of their having been waterborne, while at the same time their exact resemblance to the neighbouring bed of quartzite is strong evidence in favour of their having been derived from it.

The amount of pressure to which these shales have been subjected, though probably not so great as that which the Howth rocks have repeatedly undergone since cambrian times, has, nevertheless, been sufficient to elevate the great mountains of the Arrakan Yoma, and to fold and contort the shales to a vast extent. The

[1] Proc. Geologist's Assoc., Vol. XIII, Pt. 4, 1893. The Geology of Dublin and its neighbourhood.

cleavage and bedding of the shales appear to correspond and, where not vertical, the prevailing dip is at a high angle (80° and over) to east or west. Everywhere overfolds, faults and broken-backed anticlinals are seen, and it is almost impossible to estimate even roughly the true thickness of these beds which extend, at any rate in the neighbourhood of Shauktaung and Won, over more than six miles of country. Nor does the possibility of the discovery of fossils in beds which have been so crushed seem to be anything but exceedingly remote.

Further notes *on the* Lower Vindhyan (Sub-Kaimur) area *of the* Sone Valley, Rewah, *by* P. N. DATTA, B.SC., F.G.S., *Deputy Superintendent, Geological Survey of India.*

'Lower Vindhyan' area surveyed this season.

The area surveyed in 1895-96 includes the ground bounded on the north by the Kaimur scarp and on the south by the Sone River, and extending from the neighbourhood of Churhat (Lat. 24° 25'·5, long. 81° 42'·5) on the west, to the extreme limits of the State of Rewah on the east.

Combined extent of Lower Vindhyan areas surveyed during 1894-95-96.

Thus the lower Vindhyan area examined on the west during the season 1894-95 together with that surveyed this season (1895-96) on the east makes up almost the entire strip of land situated between the Kaimur scarp on the north and the Sone on the south, in the Rewah State.

Lower Vindhyan beds classified into four stages.

As the result of my examination of the ground during the season 1894-95, I found that the lower Vindhyan system clearly admitted of arrangement into four broad, well marked stages,[1] namely, the Rhotas, Kheinjua, Porcellanic and Conglomeratic stages, in place of the eleven 'subdivisions' into which Mr. Mallet had proposed to classify it.[2] My examination this season (1895-96) of the eastern continuation of the same beds, as were met with during the season 1894-95 in the western parts, has further convinced me that Mr. Mallet's subdivisions of the lower Vindhyan system are not tenable.

Mr. Mallet's eleven 'subdivisions' not tenable.

For while some of these subdivisions are extremely limited in extent, being in fact altogether more or less local, beds have been made to form a subdivision which are not only local but also not very definable; and again, many of the proposed 'subdivisions,' through lack of possession of characters important and distinctive enough, are not entitled to the rank of 'stages' properly so called. Under these circumstances the classification of the lower Vindhyans into the so-called subdivisions, eleven in number, can hardly be retained, and their arrangement into the four stages, Rhotas, Kheinjua, Porcellanic and Conglomeratic, seems about the best we can have under our present state of knowledge.

[1] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 145.
[2] Mem. Geol. Surv. Ind., VII, p. 28.

We will take up the stages severally and notice the peculiarities, should there be any, in their extension in the eastern area. Beginning with the youngest we have the—

Rhotas stage.
Limestone is of the same character as on the west.

Rhotas.—Though the bulk of the stage is concealed under alluvium in the eastern parts, it is apparently composed of thin-bedded limestone of much the same kind and character as on the ground to the west.

Shaly band, No. 10 of Mallet's subdivisions, not traceable.

The band of argillaceous shales stated to occur in the upper parts of the stage forming subdivision No. 10 of Mr. Mallet[1] could nowhere be clearly seen in the area under report. These shales are, however, stated to occur between Rajgurh and Rewasin Hill.[2] That Rajgurh is probably a misprint for Ramnaggar would appear from the occurrence of a locality of the name of Ramnaggar in about the identical position of 'Rajgurh' in the map accompanying Mr. Mallet's Memoir. Taking Ramnaggar and Reiwas Hill then for 'Rajgurh' and 'Rewasin' Hill, hardly any clear exposures of even the upper beds of the stage are obtainable in this area, to say nothing of an intercalated band of shales in them. But certainly at the foot of the scarp by Baghawa (Lat. 24° 29', long. 81° ·50'), Diholi (Lat. 24° 30', long. 81° 53'), and a few other localities, I observed debris of what looked like argillaceous shales; but as in none of these places could I discover any indications of lamination or bedding in them it was not possible to make sure whether what was observed was the debris of the Bijigurh shales washed down the slopes from above or really shales *in situ*.

Kaimur-Rhotas junction.

As to the junction of the Rhotas limestone with the Kaimurs above. In my report of last year I gave it as the result of my examination of the Kaimur-Rhotas junction in the area from N.W. of Intwa, *i.e.*, about long. 81° to near Churhat (long. 81° 38') that no evidence of unconformity was discovered at this junction, but there were, on the contrary, indications of a gradual passage from the Rhotas limestone into the Kaimur beds above, this passage being indicated by a fine grained, homogeneous chalky shale, as exposed by Hinaota, Daorahra, Majgama, etc.[3] The examination of the ground was extended this season from long. 81° 38' to long. 82° 30', and the following sections are of interest as bearing on the question of the nature of the junction of the lower Vindhyans (Sub-Kaimurs) with the upper Vindhyans:—

Sections bearing on the nature of the junction.
Ginaor section.

Ginaor.—(*Lat. 24° 27'·5, long. 81° 42'*).—There are two little hillocks at the foot of the Kaimur scarp by this village. At the eastern extremity of the western hillock is exposed a gentle anticline formed by sandstone (Kaimur), in the centre of which is seen a darkish grey subporcellanic rock exactly like that observed last season between the Rhotas limestone below and the Kaimur beds above. This subporcellanic shaly rock passes up into a light gray laminated soft shale which is overlaid by the sandstone forming the top beds of the anticline. This sandstone is the continuation of the lowermost beds of the sandstone exposed on the adjoining Kaimur scarp. The Rhotas is not exposed here, but there is little doubt but that it comes in just below the subporcellanic shaly beds. Thus all

[1] Mem. Geol. Surv. Ind., VII, pp. 28, 42.
[2] Mem. Geol. Surv. Ind., VII, pp. 42, 43.
[3] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 149.

that we can see here is that the subporcellanic silicious shaly rock passes up into a soft light grey shale which in turn seems to pass up into the sandstones of the Kaimur scarp.

Tikat section.

Hillocks by Tikat (*Lat.* 24° *28'·5, long.* 81° *46'*). – There are three little hillocks here at the foot of the Kaimur scarp. Rising as they do from the alluvium of the plains, these hillocks are seen to be composed of subporcellanic silicious shales, which are well exposed on their southern slopes, and are capped by thin-bedded sandstone. No marked thickness of laminated soft shales occurs here, but these seem to be immediately overlaid by the sandstone. The uppermost shaly rock does not seem to be an admixture of argillaceous and arenaceous materials, but while the shale is exceedingly fine grained and seems argillaceous (but may be somewhat silicious) the sandstone seems entirely arenaceous and is not very fine grained. Thus there appears to be here an absence of a true passage of material from the one set of beds into the other. But though this is so, there is a perfect parallelism of bedding between the shales and the sandstone. The Rhotas below the subporcellanic shales is not exposed here.

Baghawa section.

Baghawa (*Lat.* 24° *29', long.* 81° *50'*). – The foot of the scarp slopes N.-W. of Baghawa, exposes sections exactly similar to those near Tikat. Here, at one spot, the topmost layer, 2" thick, of the silicious shale could be traced for a few yards along the junction with a perfect dip-conformity with the overlying sandstone, although in the character of the constituent materials the shales and the sandstone were sharply separated, one being of fine argillaceous material (might be somewhat silicious) and the other purely arenaceous.

Diholi section.

Diholi (*Lat.* 24° *30', long.* 81° *53'*) – At a point at the foot of the Kaimur scarp N. by W. of Diholi is seen a section quite similar to the preceding, but here the limestone (Rhotas) is exposed in addition, underlying the subporcellanic silicious shales. These shales are very well seen here, being light to dark grey in the lower parts and rather finely laminated in the upper parts. The junction of the sandstone with these shales is as in the preceding section, but the contact of the latter with the underlying Rhotas is not exposed. A couple of shallow pits were dug here with a view to getting at the contact but the digging was abandoned owing to prevalence of sandstone and shale debris. The point of interest, however, here is that all the three sets of beds, namely, the Rhotas, the superjacent silicious shales, and the sandstone overlying the last, are all well exposed exhibiting a perfect parallelism of bedding between one another.

By *Maraoli* (*Lat.* 24° *33'6, long.* 82° *20'·25*), *and Khairpur* (*Lat.* 24° *34', long.* 82° *25'*). – Rhotas is visible by the foot of the scarp slopes, but the junction with the beds above is obscured by talus.

Hurma (*Lat.* 24° *31'·5, long.* 82° *34'*).—On the scarp slopes here the limestone (Rhotas) is followed up the slopes for some way, but its junction is more or less obscured by shaly debris from above.

Ground E of Hurma.

Sections *E. of Hurma.* – In the ground eastwards of Hurma and as far as the limits of Rewah, fairly clear sections are not unfrequently met with; but the subporcellanic silicious shales between the Kaimur sandstone and the Rhotas limestone, hitherto noticed so often on the west, seem to be absent there. But the parallelism of the limestone beds of the

Rhotas stage with those of the overlying sandstone of the Kaimurs is maintained throughout.

Thus from the sections above recorded we find that while near Ginaor the sub-porcellanic silicious shales pass up into a shale which in turn seems to pass up into a sandstone, this latter shale is little developed by Tikat. Throughout the greater part of the area in sheet 474 (*i.e.*, from long. 82° 0' to 82° 20') the rim of the upper Vindhyan basin seems depressed and the Kaimur sandstone comes down to the level of the alluvium of the plains. Eastwards of this point the Rhotas is again visible by the foot of the scarp, but the silicious shales are no longer traceable, being apparently absent, the result being that the Rhotas is in direct contact with the sandstone of the Kaimur scarp. These last two sets of beds, however, exhibit a thorough dip-conformity throughout.

Inferences drawn from the sections.

From these observations and those recorded last year we are led to infer :—

i. That there is a passage from the Rhotas limestone into the Kaimur sandstone through a homogeneous white shale, as observed by Hinaota, Daorahra,[1] etc., and a subporcellanic silicious shale which itself passes up into the overlying sandstone.

ii. That the above mentioned shales—the homogeneous white shale, the silicious shale, etc. – die out towards the east, and that there is an overlap of these by the Kaimur sandstone which thus rests directly on the Rhotas limestone in the eastern parts.

iii That this overlap would explain the abrupt juxtaposition of a coarse rock like the sandstone of the Kaimurs and of a fine-grained, homogeneous deposit like the Rhotas limestone, an abruptness that has hitherto been held to be universal and as such been insisted on as evidence of unconformity between the lower and the upper Vindhyans, but which appears now to be not universal but only local, obtaining over only parts of the area, and being replaced in other parts by a gradual passage from the limestone of the Rhotas into the arenaceous beds above.

iv. That though thus there is an overlap in certain parts by the Kaimur sandstone of the shales that come in immediately above the Rhotas, there is no unconformity between the lower Vindhyans (sub-Kaimurs) and the upper Vindhyans.

The Kheinjua stage.

Kheinjua stage.—As most of the area examined this season is under a general cover of superficial deposits, exposures for close examination of the beds were very few and imperfect, and thus it was not possible to arrive at a more minute and detailed classification of the Kheinjuas than that recorded last year.[2] Hence last year's classification of the

[1] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 149.

[2] These are the 8 zones into which the Kheinjuas were divided :—(l`escending order).

i. Argillaceous shales, with calcareous concretions, etc.

ii. Limestone band.

iii. Shales, with thin-bedded sandstone, ripplemarked.

iv. Limestone, with shales ; limestone ripplemarked, impure with quartz and other enclosures.

v. Shales, argillaceous and arenaceous, ripplemarked, with thin bands of sandstone.

vi. Sandstone, thick bedded and quartzitic.

vii. Limestone with shales.

viii Shales and sandstones.

See Rec. Geol. Surv. Ind., XXVIII, p. 146.

Kheinjua stage, namely, into 8 zones, has been retained, and endeavour has been made to correlate the sections available in the eastern area with those of the western. The main results are that while zone i (upper part of Mr. Mallet's subdivision No. 8) and zone iv (subdivision No. 7 of Mallet's) are fairly persistent and traceable almost throughout the area, the limestone of zone iii is nowhere exposed in this eastern area, nor is the zone vii well defined, though a thin limestone band does occur in parts of the area not far from its horizon, such for instance as the calcareous band 1 mile S of Churhat (Lat. 24°25'·5, long. 81°42'·5). Zone iii no doubt occurs probably throughout the area though it is not open to examination owing to superficial deposits. The absence of the thick-bedded quartzitic sandstone band, *i.e.*, zone vi. (part of subdivision 6 of Mr. Mallet's) coupled with the circumstance that the limestone of the zone vii is not generally developed or traceable, adds to the difficulty of separating v from viii. Thus where there is no limestone in the lower parts of the division, zones v-viii are not distinguishable among each other.

Reported absence of limestone of zone iv, *i.e.*, of subdivision 7 of Mr. Mallet's at Bardhi.

Reference may here be made to one or two of Mr. Mallet's remarks recorded by him with reference to the Kheinjuas.—Mr. Mallet says that the limestone of his subdivision No. 7 is absent at Bardhi.[1] Now there can be no question that there is a broad band of limestone well exposed on either bank of the Gopat by the south-western end of the village of Bardhi, and that it occurs as part of the Kheinjuas and is overlaid by thin-bedded sandstones and argillaceous shales containing calcareous concretions which certainly belong to Mr. Mallet's subdivision No. 8[2], and is underlaid by shales and thin-bedded sandstone with some more beds (*i.e.*, the lowermost, probably shales) that are concealed. But as porcellanic shales (No. 5 of Mallet's) come in just below the last mentioned set of beds—the shales and thin-bedded sandstones—there can hardly be much doubt that these shales and sandstones represent his subdivision No. 6, and consequently the Bardhi band of limestone must belong to his subdivision No. 7. While the existence of the subdivisional limestone No. 7 is altogether denied at Bardhi, not only is there no position whatever assigned in Mr. Mallet's classification to the prominent band of limestone of Bardhi but it is not so much as even alluded to as occurring here.

Alleged absence of subdivisions 7 and 6 of Mr. Mallet's at Bardhi.

With regard to the statement that the concretionary shales (*i.e.*, part of Mallet's subdivision No. 8, or zone i of the Kheinjuas of my classification) rest directly on the porcellanic shales at Bardhi, and that consequently the intermediate beds (*i.e.*, his subdivision Nos. 7 and 6) are entirely undeveloped there,[3] the following section by Bardhi will make it at once evident that a good thickness of those intermediate beds (subdivisions 7 and 6) do occur there and that thus the concretionary shales of subdivision No. 8 do not rest directly on the porcellanics at or near Bardhi.

Section N. by W.—S. by E. by Bardhi.

(DESCENDING ORDER.)

a. Argillaceous shales, dark grey to blackish, containing calcareous concretions, passing down

[1] Mem. Geol. Surv. Ind., VII, p. 38. The locality is here named "Burdhee."

[2] Mem. Geol. Surv. Ind., VII, p. 40.

[3] Mem. Geol. Surv. Ind., VII, p. 38.

into a thin band of finely laminated light grey to whitish shale with crystals of quartz. Well seen on the left bank of the Sone, N. W. of Bardhi.

b. Blank.

c. Thin-bedded sandstone (with an occasional thick bed), with subordinate bands of shales. These are the beds on which Bardhi itself stands and are well seen on the right bank of the Gopat here.

d. Limestone with shales: composed of an upper band of grey, yellowish to pinkish limestone, thick bedded and cherty, succeeded by greenish argillaceous shales and these being underlaid by a thinner band of rather impure limestone with intercalations of arenaceous layer. Well exposed on the right bank of the Sone at 2½ miles W. by N. of Bardhi; seen also on the Gopat just S. W. of Bardhi itself.

e. Shales, greenish (argillaceous as well as arenaceous), with thin-bedded sandstone.

f. Blank.

Porcellanics.

In this section:

(*a*) represents zone i of the Kheinjuas, *i.e.*, uppermost part of Mr. Mallet's subdivision No. 8; zone ii may be present but is not exposed;

(*c*) " zone iii, *i.e.*, lower parts of 'subdivision' No. 8; and evidently the next lower beds, namely,

(*d*) represent zone iv, *i.e.*, subdivision No. 7 of Mallet's, and that

(*e*) and the concealed beds of blank f, represent v, vi and viii (vii in all probability being absent from the section), that is, subdivision 6 of Mr. Mallet's. Thus a tolerably good thickness of beds of 'subdivisions' 7 and 6 are interposed between the shales containing calcareous concretions belonging to No. 8 of Mallet's subdivisions and the porcellanics in the neighbourhood of Bardhi.

Trappoids generally absent.

Porcellanic stage.—Of the three-fold division of the porcellanics, namely, into upper porcellanics, trappoids and lower porcellanics, as indicated from the examination of the ground in the western parts,[1] the trappoids seem more or less absent in the area examined this season. They (the trappoids) being the coarser beds it is only to be expected that they would be more or less local in extent and distribution Thus in this eastern area the porcellanics consist generally of shales of a porcellanic character together with intercalations of ordinary argillaceous shales, with only very local, occasional, coarser beds—the remnants of the old 'trappoids'.

The porcellanics as a band are traceable as far as Agarwar(Lat. 24° 32'·5, long. 82° 41'·5). Eastward of this surface deposits predominate to such an extent as to conceal all further exposures, and the course indicated by the porcellanics is therefore to some extent conjectural.

Limestone of 'subdivision' No. 2 of Mallet's cannot be maintained as a subdivision of the basal stage.

Conglomeratic stage.—This, the basal, stage of the lower Vindhyans (sub-Kaimurs) was proposed last year to include beds of subdivisions Nos. 2 and 1 of Mallet's.[2] Further observations this season have not only convinced me as to the propriety of including the limestone of subdivision 2 in this stage, but also that the limestone forming Mr. Mallet's subdivision No. 2 cannot be maintained as a subdivision proper at all, but that it can be regarded only as a zone in the stage. For there is no limestone constantly present occupying a horizon intermediate between the porcellanics and the subdivision No. 1 (Mallet's); in fact in the area

[1] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 146.

[2] Rec. Geol. Surv. Ind., XXVIII, pt. 4. p. 147.

under report a limestone could be detected only for a few miles in this position. Even when it does occur in this position it is not present as a thick mass, nor does it exhibit any characteristic peculiarities entitling itself to any prominence, but on the contrary it shows an intimate connection and association with the underlying beds, as if it formed a part and parcel of them. Added to this is the circumstance that it does not present an uniform and persistent character in all its outcrops but is of a character exceedingly inconstant and variable. There certainly does occur in many places in the area under notice one thin calcareous band, or more, in this conglomeratic stage but the position of its occurrence varies, it being sometimes in the upper parts of the stage, sometimes about the middle and occasionally rather near the base than otherwise. So the arrangement of the conglomeratic stage into two subdivisions, namely, limestone and conglomeratic and calcareous sandstone that was suggested must be given up. As to any new grouping of the beds: Of the ground surveyed this season by me the conglomeratic stage comes in only in part of it and even in this limited area alluvium prevails over a large portion and thus exposures available for a minute examination were exceedingly few and unsatisfactory. Under these disadvantageous circumstances any attempt at a minute classification—a classification that would hold good generally—had to be given up and all that has been found possible is to suggest an arrangement of the beds of the stage into two broad subdivisions, namely:—

Horizon of the calcareous band or bands in this stage variable.

Classification of the beds of the stage into two subdivisions.

(DESCENDING ORDER.)

i. Shales and thin bedded sandstones, with one or more of calcareous bands.
ii. Sandstones, rather thickest bedded and often rather quartzitic, with conglomeratic quartzite or sandstone.

Notes from the Geological Survey of India.

Mysore.—During a recent tour of the Director his attention was drawn by Dr. J. W. Evans, senior Geologist to the Government of Mysore, to certain peculiarities of the so-called Champion reef in the Kolar gold-field, which show that it is not a reef or vein, but a true bed of metamorphic quartzite. The lie of the quartz is strictly conformable to that of the schists on either side, and in more than one place it has been bent sharply up and then down again into a synclinal and anticlinal fold, whose axis dip steeply to the northwards. Where the quartz is bent, the bedding of the hornblende schists follows it and can be seen curving over the vacant spaces where the quartz has been worked out. There can be little doubt that Dr. Evans' interpretation is the true one, and that the gold of Mysore, as of the Transvaal, occurs in a bed, and not in a true vein. This discovery is of interest as adding yet another to the many analogies between the geology of India and Africa, and is not without its bearing on the economic question of the life of the Kolar gold-field.

R. D. OLDHAM.

RECORDS

OF THE

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.]	1897.	February.

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1896.

1. At the commencement of the year the disposition of the officers of the Survey was that stated in the last annual report. During the year Dr. Warth and Mr. Anderson resigned their appointments, the first on the 15th March, the second on 1st September 1896.

Two officers have been granted furlough. Mr. Griesbach on 16th May, Mr. Datta on 17th September 1896.

Both sub-assistants are absent on leave, Lala Kishen Singh on medical certificate from 1st October 1896, and Lala Hira Lal on privilege leave.

Dr. Nœtling and Mr. Bose have been absent on furlough throughout the year.

Mr. LaTouche returned from furlough on 13th October 1896.

2. Owing to retirements and departure of officers on furlough, the Survey is working very short-handed during the present year; the disposition is as follows:

MR. MIDDLEMISS	Madras.
„ HOLLAND	Madras.
„ LATOUCHE	Western Rajputana.
„ SMITH	Assam.
„ VREDENBURG	South Rewah.
„ GRIMES	Burma.

Sub-Assistant Hira Lal will be posted to Madras on return from privilege leave, if his services are required by Mr. Middlemiss; if not required, he will be kept at head-quarters to assist in the transfer of the office of the Survey into the new building.

3. *Madras.*—The survey of the Salem and Coimbatore Districts has been energetically pushed forward, and it is expected that it will be completed in 1897, when a full report of the results will be submitted. The most important of these at present is the conclusion Mr. Middlemiss has come to, that the massive granitoid gneiss of Hosur, which had been regarded as probably older than the other types (*Manual*, 2nd edition, p. 35), cannot be said to be older or younger than the charnockite gneiss, or to underlie or overlie it. At the limits of the two types of gneiss, they

Mr. C. S. Middlemiss.
„ F. H. Smith.

are seen to end in long tongues which interlock with each other, while a perfect mineralogical passage from one type to the other has been observed.

4. In the neighbourhood of Satyamangalam, some patches of quartz schist, containing numerous crystals of kyanite—which was at one place reported as corundum—are regarded by Mr. Middlemiss as probably highly metamorphosed Dharwars. The southern extensions of the main outcrops of this series, in its typical form, have been mapped. In many cases, the nature of the boundary suggests that the gneiss is in reality an intrusive granite, as there is a band of it crowded with fragments of Dharwar rock, resembling inclusions. This is not the true explanation according to Mr. Middlemiss, however, as there are many sections where the Dharwars are clearly unconformable on the gneiss; and he considers that the apparent inclusions have been produced by a post-Dharwar softening of the gneiss and movements of the rock while in this condition.

5. An interesting fact in connection with the Dharwars, which may be noticed here though we owe it to Dr. J. W. Evans, Senior Geologist to the Mysore State, is the discovery that the so-called reefs of the Kolar goldfield are not reefs in the ordinary sense of the word, but true interbedded quartzites of the same character as the famous gold-bearing deposits of the Transvaal.

Gold.

In the neighbourhood of Kollegal, some gold-bearing reefs were examined by Mr. Middlemiss. One of these near Kavudahalli (Cowdalli), is now being exploited by a mining company and good lodes carrying 1 to 2½ ounces of gold to the ton are said to have been found. It is noteworthy that Mr. Middlemiss considers that the rocks of the Kavudahalli field do not belong to the Dharwar series, as was suggested by Mr. Foote (*Records* XXI, p. 55). Mr. Foote, it must be remembered, had not visited this locality, and his suggestion that the Dharwar series might be represented there was purely an inference from the known existence of old workings, and the fact that in the country he had surveyed all the gold-bearing rocks were confined to the Dharwar series. It was known that the gold of the Wynaad occurred in rocks very different to those of the Dharwar series in its typical exposures, but in the absence of a special examination, the possibility remained that the difference might only be due to a greater degree of metamorphism. Mr. Middlemiss' work makes it more probable that the difference is a real one, and that the gold of Southern India is bound in two different rock systems and is not confined to one. The discovery, noticed above, that the gold-bearing rock of the Kolar goldfield is a true metamorphic quartzite, suggests that the gold is of derivative origin, and is consequently an independent indication of an older series of gold-bearing rocks, from which the gold was derived.

Corundum.

6. Concurrent with the purely geological survey, the special investigation of the corundum-bearing rocks has been actively carried on, and has resulted not only in the discovery of many new localities, but, what is more important, of the fact that the corundum occurs in definite bands of rock which can be followed with almost the same certainty as a seam of coal. One such band—known as the Paparapatti band—has actually been traced continuously for a distance of 36 miles.

7. The preliminary survey being sufficiently advanced to render the commencement of exploratory workings desirable, with a view to testing the extent and richness of the corundum-bearing rock, arrangements were made with the Govern-

ment of Madras for the carrying out of this work. Owing to the resignation of Mr. Anderson—who had been intended to take charge of this work—a modification of the original plans had to be made, and it was arranged that a series of excavations should be made by the Public Works Department, at places to be pointed out by Mr. Middlemiss. These excavations or quarries as they will be, are intended to show the thickness of the corundum-bearing bands, and whether they are continuous or occur as lenticular patches. A fair average sample of the rock extracted, of sufficient size to give a trustworthy estimate of the richness of the rock, is to be carefully cleaned by hand and the proportion of corundum to matrix determined by weighing. Samples of the cleaned corundum and of the rock will then be sent to the Secretary of State for submission to experts with reference to (1) the value of the cleaned product and (2) the best means and probable cost of separation. Owing to the fact that each crystal of corundum is surrounded by a shell of felspar, from which it separates as readily as the kernel of a nut from its shell, there will be no difficulty about the mechanical separation of the corundum from its matrix, and the whole question of the possibility of working these deposits on an industrial basis will resolve itself into the three questions, of quantity of ore, value of the finished product, and cost of production. The first of these will be determined by the operations carried out locally ; for the latter two, the reports of the experts will give the answers. In this manner, a result will be attained both more satisfactory in itself and more economically than by the employment, on purely exact executive work of a nature that does not require any very high standard of attainments, of a highly paid specialist, who would not have been able to answer the questions which must be submitted to European or American experts.

Operations are now in active progress, and the results of the first weighings give 150lbs. of clean corundum from 1 ton of rock.

Iron.

8. Several new discoveries of iron ores have been made during the progress of the survey and previously known sites re-visited. An application has also been made by the Government of Madras for the examination of the iron ores of Kurnool, but in view of the report of Mr. Jeremiah Head, addressed to Her Majesty's Secretary of State for India, dated 2nd May 1896, which shows that there is no possibility of locally manufactured charcoal iron competing with the imported product, all special investigations of iron ores in Madras would appear to be a waste of time. In the case of the iron ores of Kanjamalai, near Salem, it has been decided to send 100 tons home for an exhaustive trial on a large scale, and until the results of this are known, any special examination of iron ores, apart from what can be done in the course of regular survey, is to be deprecated.

Steatite.

9. In February an application was made by Messrs. Sugg and Company for a consignment of 20 tons of steatite from the Kurnool District and this department instructed to inspect the consignment before despatch. The necessary instructions were accordingly issued to Mr. Middlemiss, who reports that of the 28 tons, which were extracted by the District authorities, a large part was in too small fragments to be of any use, and only a very small proportion reached the dimensions which appear to be required. He has condemned 13 of the 28 tons and recommended that the other 15 be forwarded to Messrs. Sugg and Company for trial.

10. *Bengal.*—At the commencement of the year, the party was still engaged on exploration, but in February a site was selected by Mr. Anderson where mining operations were commenced and stamps set up, but there was great delay in starting them, a delay ostensibly due to the non-supply of certain requisite stores, the exact description of which I had great difficulty in obtaining from Mr. Anderson. The final results of the crushings were disappointing and inconclusive beyond showing that the quartz at Dhobni near Borobhum, worked by Mr. Anderson, contained practically no gold.

Chota Nagpur.
Mr. W. Anderson.
Dr. H. Warth.
Lala Hira Lal.

11. *Central India.*—During the working season of 1895-96 the survey of Rewah had been practically completed and would doubtless have been finished, but for the phenomenal unhealthiness of the season, Messrs. Datta and Grimes were both completely prostrated before the end of the season, while among the establishment and servants fever was rampant.

Rewah.
Mr. R. D. Oldham.
" P. N. Datta.
" E. Vredenburg.
" G. E. Grimes.

12. The work in the rocks which have been grouped for convenience as transition has resulted in the establishment of at least one well-marked unconformity. The existence of this had been suspected from the previous season's work, but, though now well established, it will not be possible at present to devote the time necessary for detailed mapping to the determination of the exact distribution of the two series. It is also extremely doubtful if this could be done without a more perfect topographical map, on a larger scale than is at present available.

13. In the Vindhyan system, Mr. Datta's survey seems to show that there is a complete conformity between the lower and upper Vindhyans along the boundary at the foot of the Kaimur scarp. Certainly if there is any unconformity it is of the slightest, extremely difficult of detection, and in most striking contrast to the well-marked unconformity observable a few miles to the southwards, as described in *Records* XXVIII, p. 139. This contrast in the relations of the series at places, so close together, is a strong support of the suggestion regarding the nature and mode of origin of the Vindhyan sandstones, first propounded in the *Manual of the Geology of India*, 2nd edition, p. 104.

14. In the Gondwana area, the survey of the western extension of the Singrauli coalfield was carried out and some discoveries of interest made in the course of it. In the Talchirs of Singrauli, a large number of the included boulders were found to show striation and polishing, resembling that to be seen on the boulders in glacier moraines, and more especially in what is known in Switzerland as "Grund Morän." This is not only a new locality for these scratched boulders, but one in which they are more abundant and perfect than has yet been recorded from the Talchir boulder bed of the Peninsula.

15. In the area occupied by the Damuda rocks, a number of coal seams were observed; the assays of the specimens brought to Calcutta have given poor results, but it must be remembered that they were only weathered specimens from the outcrop. There is here a large coalfield with an abundant supply of coal, but too remote from the existing lines of communication to hold out any prospect of successful working in the immediate future.

Coal.

16. An interesting collection of fossils was made; amongst them, a cluster of

fronds of *Glossopteris* attached to their rootstock, which shows the characters of *Vertebraria.* A somewhat similar discovery of *Glossopteris* fronds attached to *Vertebraria* has been recorded from South Africa,* and the true nature of that mysterious fossil known as *Vertebraria* may now be taken as settled.

17. It is noteworthy that the numerous intrusions mapped are all basaltic and that none of the peridotites which have been described by Mr. Holland from the eastern coalfields of Bengal were observed.

Lala Kishen Singh.

18. *Baluchistan.*—During the working season of 1895-96, Sub-Assistant Kishen Singh was engaged on the survey of the Chehiltan range and part of the Khwája Amrán, and in the collection of fossils from the hills near Khelat. According to his report, the Khojak shales underly the 'massive limestone' (jurassic) with a marked unconformity. This observation, if confirmed, is inconsistent with the eocene age ascribed to the former rocks by Mr. Griesbach in his original report (*Memoirs*, XVIII), and subsequently confirmed by the discovery of nummulites, as announced in the Annual Report for 1894; on the other hand, it is in accordance with the conclusion, adopted in the second edition of the *Manual*, that these shales are older than tertiary, and not impossibly triassic in age. The grounds for this correlation are, as was stated, very inadequate; no fossils had then been found in any part of them, and it was only the exigencies of classification that led to any definite age being ascribed, even conjecturally. The most probable explanation is that the Khojak shales belong to more than one stratigraphical series, and that the apparent discrepancy will vanish when this region is fully surveyed.

19. The collection of fossils from the neighbourhood of Khelat has not yet been examined, but Dr. Carter's discovery of *Orthoceras* has not been repeated.

Mr. T. D. LaTouche.

20. *Rajputana.*—The survey of Rajputana has been resumed during the present working season, and Mr. LaTouche is engaged in Southern Marwar. The commencement of field work was delayed by causes beyond control and no results of importance can yet be reported.

Simla.
Mr. H. H. Hayden.

21. *Punjab.*—During part of the recess season, Mr. Hayden was deputed to complete the geological survey of Simla and Mahásu, of which a preliminary account was published in *Records*, Vol. XX, p. 143. Besides some minor modifications in detail of the mapping of Simla proper and the extension of the survey over the Mahásu ridge, Mr. Hayden was able to complete the examination of Jutogh, to which I was unable to devote more than a slight attention in 1887, and to determine in detail the sequence of the rocks grouped as the upper or Jutogh carbonaceous slates and limestones.

22. In the course of this survey, some light has been thrown on a vexed question in the geology of Simla and Jutogh. It has long been known (see H. B. Medlicott, *Memoirs* III, pt. 2, p. 34) that the rocks at the summit of Jako show a much higher degree of metamorphism than in the bottoms of the surrounding valleys; where we find slates and phyllites, from which there is a passage, as the hills are ascended, though more and more schistose rocks, to a highly crystalline garnetiferous mica schist. In 1887, I discussed the three alternative explanations which were possible, but the facts then collected were insufficient to decide between them. Mr. Hayden's observations indicate the probability that in the case of

* R. Zeiller. Comptes Rendus, CXXII, p. 744, and Bull. Soc. Geol., France, 3rd Ser., XXIV, p. 349.

Jutogh at least, there is a central core of igneous rock to whose intrusion the metamorphism of the beds is due. He finds that the whole series of beds on the Jutogh hill show unmistakeable signs of contact metamorphism and in two places intrusive diorite was found in the form of numerous dykes and veins cutting the sedimentary rocks, which had been altered almost beyond recognition.

Naini Tal.
Mr. T. H. Holland.

23. *North-Western Provinces.*—The investigation of the stability of the hill sides in Naini Tal has been completed and a full report published. As originally proposed, this investigation was to have been carried out by an officer of the Geological Survey in conjunction with an Engineer and was to have included specific recommendations as to protective measures to be undertaken. Owing to various causes this programme was not carried out, and the investigation and report were made by Mr. Holland alone. It is a very complete and, it is anticipated, final statement of the conditions of the problem, the nature of the dangers to be apprehended, and the character of the remedied measures required. The execution of these, when decided on, must be left to the Public Works Department, which will find in Mr. Holland's report the fullest information regarding those aspects of the problem which would not come within the cognizance of its officers, but which must be attended to if more harm than good is not to result from its operations.

Mr. F. H. Smith.

24. *Assam.*—The survey of Assam has been resumed during the present working season, and Mr. Smith is at present engaged on the survey of the eastern part of the Mikir hills. It is hoped that some light may be thrown on the manner in which the cretaceous and nummulitic rocks pass north-eastwards, and on the manner of their final disappearance. It is probable too that coalfields of value to the Assam-Bengal Railway may be met with in the course of the survey.

Burma.
Mr. H. H. Hayden.
" G. E. Grimes.

25. During the field season of 1895-96, Mr. Hayden was employed in Burma, following the precedent of former years, under the direct orders of the Local Government. After the completion of the examination of the Sagyin ruby tract, which was referred to in last year's report, he was instructed to examine the Mithwe coalfield, a yellow ochre deposit near Panpé, and the steatite mines which were reported to be situated in the Minbu District, but which were found to be in the Kyaukpyu District of Arakan.

Coal.

26. The Mithwe coalfield is situated about 5 miles south-east of Lagat and consists of tertiary clays, sandstones and conglomerates. The coal occurs in thin seams, the best of which is 2' 8" thick, but only extends for 112 feet along the outcrop; it is shaly and poor, and the beds are highly disturbed, faulted, crushed and penetrated by intrusions of gabbro, diallage rock and serpentine.

Ochre.

27. Of the yellow ochre deposit little more need be said than that it exists, with a varying thickness, whose maximum is 30 feet.

Steatite.

28. The steatite of the Kyaukpyu District is found in considerable quantity and has hitherto been mined at two localities, about 30 miles west of the village of Hpa-aing and near Senlan village in Ngape township. Both these villages are in the Minbu District, but the first named mines are on the west on the watershed, and consequently in the Kyaukpyu District. The mines descend as much as 200 feet by narrow tortuous shafts,

and are abandoned in the rains owing to the influx of water, and the risk the miners run of finding themselves shut in by falls of rock in the untimbered shafts and galleries.

29. These results cannot be regarded as satisfactory either from a scientific or economic point of view. For this, Mr. Hayden can in no way be held responsible; on the other hand, his work, carried on under circumstances of exceptional difficulty, attended by no small hardship, and in spite of his being hampered by the want of proper maps for the execution of a geological survey, the scattered distribution of the localities visited, and by the imperfect, where not misleading, information supplied to him, is deserving of the highest praise. The failure can only be ascribed to the conditions under which he worked, conditions which were necessary and advisable in the early days when the province first came under British rule, but which had unfortunately been allowed to survive their utility. All the principal known mineral tracts of Upper Burma have now been visited and examined as far as can be done in the absence of accurate topographical maps, and it is not to be expected that the Local Government, having no responsible adviser, should be able to profitably direct work of so technical a nature as the geological survey. The system has now been ended, and the geological survey in Burma been put on the same footing as in other parts of the Empire.

Petroleum.

30. The report on the Yenangyoung oilfield, referred to in the last annual report, is now in a very forward state, and will be published shortly. In it, Dr. Nœtling shows that the Yenangyoung field is already showing signs of exhaustion, and in view of this, and his belief that the field has only a few more years of life, it was determined to take up the survey of the country between the Yenangyoung and Yenangyat oilfields, with a view to determining whether there was any reasonable prospect of a fresh oilfield being found in that tract. Mr. Grimes was deputed for the work and started for Burma at the end of October; good progress has been made with the survey and already indications have been met with of the existence of a fresh oilfield, but no more definite statement can at present be made.

31. On his way to the ground, Mr. Grimes visited the Yenangyoung oilfield in order to make himself acquainted with the rocks he would meet with during his survey, and in the course of this visit observed an interesting improvement which had been adopted by the well-diggers. Formerly, the stay which a digger could make at the bottom of a deep well was to be timed by seconds, while a long period of rest at the surface was required to enable him to recover from the effects of the noxious vapours he had inhaled. Mr. Grimes noticed that they had now adopted the use of a diving dress, without the heavy weights required for work under water; the use of this apparatus has been introduced during the last five months, and there are already six machines at work. One result is the cheapening of the excavation, for instead of remaining down only a fraction of a minute at a time, the workman can now stay down for hours; another is that the depth to which a well can be dug is increased, instead of being limited to about 300 feet on account of the great difficulties encountered under the old system; and a third—the consequence of the last—is an increase of the life of that part of the field which is worked by the native method.

32. *Museum and Laboratory.*—Mr. Holland has continued his petrological studies of Indian rocks, the principal of which, during the past year, has been a study of the basic intrusive rocks of ancient date. A series of these, penetrating the crystalline rocks of Southern India, had been regarded as the underground equivalents of the lava flows of the Cuddapah series ; the petrological examination has confirmed this supposition and has besides shown them to be of unusual interest in themselves.

Mr. T. H. Holland.
Mr. T. R. Blyth.

33. The rocks are divided into three groups, which, though separated for convenience of description, pass into one another by imperceptible gradations. They are (1) olivine norite group, (2) augite norite group, and (3) augite diorite group. The order of succession of the minerals is constant throughout, the late development of the felspar in the basic types giving rise to a remarkable micropegmatitic structure.

34. The olivines in the more basic members show remarkably well-developed "reaction-borders," where they come in contact with the plagioclase crystals, and Mr. Holland has discussed the bearing of the evidence they offer on previously recorded conclusions concerning similar phenomena.

35. The most interesting feature, however, is the constant presence of micropegmatite in the augite diorite group, playing the part of groundmass to the previously crystallized felspar and pyroxene. Mr. Holland regards these patches of micropegmatite as the result of a distinctly late phase in the consolidation of the rock, and discusses the interesting bearing of these facts on the association of these basic rocks with granophyres and on the almost constant miarolitic structure of the latter rocks.

36. An important study of the corundum-bearing rocks of India has also been completed, in connection with the preparation of a memoir on the subject, now ready for the Press ; this has resulted in the discovery of some interesting facts in connection with the paragenesis of this important mineral, and especially with regard to its relations with the pyroxene granulite series, so largely developed in Madras. At Singanamaranhalli, in the Hunsur taluk of Mysore, the corundum beds were found by Mr. Holland to be associated with an intrusion of olivine-bearing rocks, similar to those of the well-known Chalk Hills near Salem, and large masses of a rock composed of a highly ferriferous enstatite with magnetite and the iron-alumina spinel, hercynite. The association here is very strikingly like that of the rocks in which the corundum (emery) occurs in the Cortland series of New York State, where there is a development of pyroxenic granulites and ultrabasic rocks, presenting characters precisely similar to those of the charnockite and norite series in South India. A similar association of corundum with hercynite, magnetite, and rhombic pyroxenes has been described on the eastern edge of the Bohemian Forest, the original home of the mineral hercynite. Specimens obtained from the Hindupur taluk of Bellary district show an immediate contact of corundum with hercynite and magnetite, whilst in Chennimalai, Erode taluk, Coimbatore district, corundum crystals are found surrounded with hercynite.

37. These occurrences of corundum stand in apparent contrast to those which have been described by Mr. Middlemiss in the Salem and Coimbatore districts, where, instead of being associated with ultrabasic rocks, the corundum appears as a member of the ordinary gneisses and is never far from intrusions of graphic granite. Such also seem to be the relations of the blue corundum discovered by Dr. Warth

in Manbhum district of Bengal. In describing the latter specimens, Mr. Holland has compared them with a similar occurrence of blue corundum with kyanite, andalusite, and damourite in Virginia, United States of America, in which Dr. Genth considers the last-named three minerals as derived from the corundum; but the Manbhum specimens offer no support to such a conclusion. The corundum crystals are well formed, with lustrous faces, and are small compared with the beautiful great crystals of kyanite, in which they lie without apparent regularity of crystallographic disposition. If the latter mineral and the mica were formed by change of the former, there would surely be the usual signs of etching and irregularity of contour due to decomposition. The case seems a very simple one of separation, under conditions of free molecular movement, of the excess of the simple base, alumina, followed by a crystallization of its silicate as kyanite, the mica being secondary and derived by irregular change of the latter mineral. Such a conclusion is in agreement with the facts and is in accordance with the commonly-observed order of events in most crystalline rocks.

38. *Personnel.*—With the end of 1896, Mr. Holland's charge of the Museum and Laboratory has terminated, as the decision has been arrived at that it is necessary, in the interests of the public service, that he should acquire a practical experience of the ordinary field work of the Survey. During the six years he has been in charge of the Museum, the record has been one of continuous progress. In addition to the numerous petrological researches and economic enquiries to which previous annual reports and the publications of the Survey bear witness, the whole of the mineral and rock collections have been rearranged, the rocks, numbering over 17,500 specimens, have been re-registered and put into such order that any required specimen can be promptly referred to, and the specimens exhibited to the public completely rearranged; the mineral and economic collections amounting to over 18,000 specimens were left in perfect order by Mr. Mallet, but the growth of the collections since his retirement has necessitated much work in rearranging the specimens to make room for the additions, and the collection has been revised and re-labelled. A guide to the mineral collection has been published, while guides to the collections of rocks and of economic geology are being prepared and will appear in due course.

39. It is not, however, too much to say that this record of work done would have been impossible, but for the zealous and efficient assistance of Mr. Blyth, whose services have been recognized by the Government of India, and rewarded by a permanent increase of salary.

40. Little work has been done in the collection of fossils, which have unfortunately fallen into a state approaching disorder. This is to be attributed in part to the lengthened absences of the Palæontologist from Calcutta, but mainly to the absence of any competent assistant to take charge of the collections and see to the necessary routine of posting the registers, storing the specimens, and attending to the periodical cleaning of the cases and renewal of labels. Mr. Blyth's time is already fully occupied, and the appointment of another assistant has become imperative if the large and valuable collection of fossils is not to lapse into a state of chaos.

41. During the year the Survey has lost the services of Dr. Warth, who retired on pension on 15th March 1896, and Mr. W. Anderson, who resigned his appointment on 1st September. Neither of these vacancies has been filled up, and as regards

the last mentioned, it is doubtful whether any advantage is to be derived from attempting to fill it up. Experience has shown that it is practically impossible to obtain men of the stamp desired when Mr. Anderson was appointed, and the reason is not far to seek. Men with technical knowledge of exploitation of minerals naturally prefer to take service with mining companies, from whom they not only expect higher salary than they are likely to get in the service of the Government, but from whom they may expect as the reward of zeal and competence, a permanent employment on an increasing income, as the venture they conduct advances in prosperity. It is also very doubtful whether the services of such men are either necessary or desirable for the work which alone can be reasonably expected of the Government. I am strongly of opinion that it will be in every way more satisfactory that all economic investigations should be carried out under the scientific supervision of the permanent officers of the Geological Survey, and that the only special assistance required is for the sinking of quarries, shafts, or bore holes, as the case may be. This is the procedure which has been adopted for the investigation of the corundum deposits of Madras (para. 7), and I would urge that the experiment be given a fair trial before a highly paid so-called specialist is again appointed to carry out work, which is well within the competence of the permanent staff of the Survey.

42. Messrs. Vredenburg and Grimes were employed in Rewah during their first season. Mr. Vredenburg has shown great thoroughness and care in the work entrusted to him and gives promise of becoming a thoroughly efficient member of the Survey. Mr. Grimes was much hampered by ill-health as already noticed; when sent into a country, the rocks of which were unknown to him, except from printed descriptions, he showed considerable power of adapting himself to the changed circumstances and has done creditable work. I have considered that he, as well as Mr. Vredenburg, may be trusted with independent charge, and they have been employed in Burma and South Rewah respectively, as has been mentioned above. Reports received from both during the past three months have shown satisfactory progress in spite of considerable difficulties encountered.

43. *Publications.*—The long-delayed Memoirs on the Bellary district, by Mr. R. B. Foote, F.G.S. (Vol. XXV), and on the Hazara district, by Mr. C. S. Middlemiss (Vol. XXVI) have been published. The contents of both have been noticed in previous annual reports. Of the Palæontologia Indica, part 1, Vol. I, Series XVI, The Fauna of the Kellaways Mazar Drik, by Dr. Nœtling, has been published. Parts 2 and 3 of the same volume and Dr. Diener's description of the lower trias fossils of the Himalayan collection are well advanced towards publication, as well as Dr. Nœtling's Memoir on petroleum in Burma. In addition, the report on the geological structure and stability of the hill slopes around Naini Tal has been published, to which reference has already been made.

Independent publications.

44. During the year two important papers have been published bearing on Indian geology. The first of these is the description by M. Zeiller of a collection of fossils from the coalmeasures of the Transvaal, to which reference has been made in para. 16. The second is the long-expected description by Professor Judd* of the collection made by Mr. Barrington Brown from the ruby mines of Upper Burma.

The crystalline limestones in which the rubies occur are associated with pyrox-

*Phil. Trans. CLXXXVII, p. 151.

enic and scapolite-bearing rocks, resembling the pyroxenic (hypersthene-bearing) rocks of Madras. These limestones are regarded as an extreme form of alteration of lime-bearing pyroxene gneisses, the formation of scapolite being described as a step in the formation of calcite from plagioclase felspar. The source of the alumina and magnesia in the rubies and spinels, and of the calcite in which these minerals are imbedded, is taken to be the basic lime felspar (anorthite) and associated minerals of the pyroxene gneisses.

45. It will be seen that according to Professor Judd the corundum and its matrix are both products of alteration of a pre-existing rock, while Mr. Holland, from his studies of the corundum-bearing rocks of Madras, regards the corundum as an original, and in fact the first formed, constituent of the rock in which it occurs. Such discrepancies must be excepted while our knowledge of the chemical reactions, which go on in the interior of the earth, remains as imperfect as it is at present, and there are sufficient differences in the modes of occurrence of the corundum of the Ruby Mines and of Southern India to render it possible, and even probable, that its mode of origin was not the same in both cases.

Library.

46. The additions to the library during the past year amount to 2,396 volumes and parts of volumes, of which 1,370 were acquired by presentation and 1,026 by purchase.

R. D. OLDHAM,

Officiating Director, Geological Survey of India.

CALCUTTA;
The 1st January 1897.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1896.

ADELAIDE.—Geological Survey of South Australia.
" Royal Society of South Australia.
BALTIMORE.—Johns Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Kon. Natuurkundige Vereeniging in Nederl.—Indie.
BELFAST.—Natural History and Philosophical Society.
BERKELEY.—University of California.
BERLIN.—Deutsche Geologische Gesellschaft.
" K. Preuss. Akad. der Wissenschaften.
" K. Preuss. Geologische Landesanstalt.
BOMBAY.—Meteorological Department, Government of Bombay.
" Natural History Society.
" Royal Asiatic Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterl. Cultur.
BRISBANE.—Geological Survey of Queensland.
" Royal Geological Society of Australasia.
" Royal Society of Queensland.
BRISTOL.—Naturalists' Society.
BRUSSELS.—Académie Royale des Sciences.
" Musée Roy. d'Hist. Nat. de Belgique.
" Société Belge de Géographie.
" Société Royal Malacologique de Belgique.
BUCHAREST.—Museului de Geologia si de Paleontologia.
BUDAPEST.—Kön. Ungarische Geologische Anstalt.
" Ungarische National Museum.
BUENOS AIRES.—Acad. National de Ciencias.
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
" Asiatic Society of Bengal.
" Calcutta University.
" Editor, *The Indian and Eastern Engineer.*
" Meteorological Department, Government of India.
" Survey of India.
CAMBRIDGE.—Philosophical Society.
" University of Cambridge.
" Woodwardian Museum.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CANADA.—Hamilton Association.
CASSEL.—Vereins für Naturkunde zu Kassel.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Kong. Danske Videnskabernes Selskab.

DEHRA DUN.—Great Trigonometrical Survey.
DES MOINES.—Iowa Geological Survey.
DRESDEN.—K. Min. Geological und Praehist. Museum.
„ Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Dublin Society.
„ „ Irish Academy.
EDINBURGH.—Geological Society.
„ Royal Scottish Geographical Society.
„ „ „ Society of Arts.
„ „ Society.
GLASGOW.—Glasgow University.
„ Philosophical Society.
GOTHA.—Editor, Petermann's Geog. Mittheilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALIFAX.—Nova Scotian Institute of Science.
HALLE.—Naturforschenden Gesellschaft.
„ Academia Cæsarea Leop.-Carol. Nat. Curiosorum.
JEFFERSON CITY.—Missouri Geological Survey.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LEIPZIG.—Kön. Säch. Gesells. der Wissenschaften.
„ Vereins für Erdkunde.
LIÉGE.—Société Geol. de Belgique.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Museum (Natural History).
„ Geological Society.
„ Iron and Steel Institute.
„ Linnean Society of London.
„ London Library.
„ Royal Geographical Society.
„ „ Institution of Great Britain.
„ „ Society.
„ Society of Arts.
„ Zoölogical Society.
LYONS.—Museum d'Hist. Naturelle.
MADRAS.—Literary Society.
MADRID.—Sociedad Geografica de Madrid.
MAINE.—Portland Society of Natural History.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
„ Royal Society of Victoria.
MEXICO.—Istituto Geologico de Mexico.
MILAN.—Sociéta Italiana di Scienzé Naturali.
MOSCOW.—Société Imp. des Naturalistes.
MUNICH.—Kon. Bayerische Akad. der Wissens.

NAPLES.—Reale Acad. delle Scienze Fisiche e Matematiche.
NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, American Journal of Science.
NEW YORK.—Academy of Sciences.
OTTAWA.—Geological and Natural History Survey of Canada.
PARIS.—Department of Mines.
„ Editor, Annuaire Géologique Universel.
„ Ministere des Travaux Publics.
„ Museum d'Histoire Naturelle.
„ Société de Geographie.
„ „ Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Lincei.
„ „ Comitato Geologico d'Italia.
„ Societa Geologica Italiana.
SACRAMENTO.—California State Mining Bureau.
SALEM.—American Assoc. for the advancement of Science.
„ Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM —Kon. Svenska Vetenskaps Akademie.
ST. PETERSBURG.—Académie Imperiale des Sciences.
„ Comité Géologique.
„ Musée Geol. de l'université Imperiale.
„ Russ. Kaiser. Mineralogische Gesellschaft.
STRASBURG.—Strasburg University.
SYDNEY.—Australian Museum.
„ Dept. of Mines and Agric., N. S. Wales.
„ Geological Survey, „
„ Linnean Society, „
„ Royal „ „
TOKIO.—Deutsche Gesells. für Natur und Volkerkunde.
„ Imperial University of Japan.
TORONTO.—Canadian Institute.
TURIN.—Osservatorio della R. Universita.
„ Reale Accad. delle Scienze.
UPSALA.—Upsala University.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissens.
„ K. K. Geog. Gesellschaft.

VIENNA.—K. K. Geol. Reichsanstalt.
" K. K. Naturhistorischen Hof.-Museum.
WARSAW.—Inst. Agronomique et forestier.
WASHINGTON.—Smithsonian Institution.
" U. S. Dept. of Agriculture.
" " Geological Survey.
WELLINGTON.—Mining Dept., New Zealand.
" New Zealand Institute.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Naturforschende Gesellschaft.

The Governments of Bengal, Bombay, India, Madras, North-Western Provinces and Oudh, and the Punjab.

The Chief Commissioners of Assam, Burma, and the Central Provinces.

The Resident, Hyderabad.

On some Norite- *and* associated Basic Dykes *and* Lava-flows *in* Southern India.

By THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

1. In the year 1890, Mr. P. Lake published a short paper describing four specimens of the Cuddapah (Kadapah) lava-flows collected by Dr. W. King.[1] This was intended, I believe, by Mr. Lake to be the first instalment of a detailed description of the Transition contemporaneous traps and their dyke-representatives in South India, in which area he had collected largely from the dykes of Bellary and Anantapur districts and the Raichur Doab, where, under the superintendence of Mr. R. Bruce Foote, he worked over areas partly covered by Transition rocks of the Dharwar system and partly by the older crystallines. Mr. Lake, however, left India towards the end of the same year, and the rocks consequently received no further attention till the commencement of 1892, when I made a tour over the

[1] *Rec. Geol. Surv. India*, Vol. XXIII, p. 259.

southern districts of the Madras Presidency, and, though mainly occupied with a different enquiry, was fortunate enough to obtain opportunities for examining a few of the dykes in the districts of Chingelput, South Arcot, Salem, Coimbatore and the Nilgiris. The specimens collected by myself have been supplemented by a rich collection made by Dr. H. Warth in the South Arcot district, whilst Messrs. Middlemiss and Smith have since been working out more thoroughly the dykes and associated crystalline rocks of the Salem district, and have kindly supplied me with some of their leading types.

All the specimens referred to in this paper are preserved in the Geological Museum, Calcutta, and as this subject will be included in the detailed researches in Salem and Coimbatore now being prosecuted by Messrs. Middlemiss and Smith the registered numbers are in all cases quoted for facility of reference to the type-specimens. I am indebted to Mr. P. Brühl, Professor of Physics in the Civil Engineering College, Sibpur, for the chemical analyses of four types of these dyke-rocks.

II.—GEOLOGICAL AGE OF THE DYKES.

2. Previous to the great outburst of Deccan trap there were at least two main periods of volcanic action in Peninsular India. In the southern portion of the Peninsula these are indicated (1) by the contemporaneous traps of the Dharwar Transition system, and (2) by the Cuddapah lava-flows of later date. So far as the specimens in our collection are concerned the petrological characters of the rocks divide them sharply into two classes. The Dharwar volcanic rocks are essentially hornblende-plagioclase rocks exhibiting marked signs of the changes which accompany the passage of normal diorites into epidiorites and sometimes hornblende-schists. The Cuddapah traps, on the other hand, are remarkably free from such signs of dynamic metamorphism. These are just such differences as might be expected from the known stratigraphical history of Peninsular India. Whilst there is abundant evidence of great crust disturbances in pre-Cuddapah times, the Indian Peninsula since that epoch has been remarkably free from disturbances by earth movements, and, as one result, the pyroxenic igneous rocks, which so readily yield to dynamic action, have been preserved with remarkable freshness.

3. The distinction between post-Cuddapah and pre-Cuddapah lava-flows might be expected to find similar expression in the dyke-representatives of these volcanic rocks; and, whilst fully recognising the danger of correlation from petrological characters alone, it must be accepted in the present instance as the only evidence of a positive character. The age of a dyke, whose connection with a known lava-flow is not manifest, can seldom be determined within very narrow limits, and even then the limit on the younger side generally depends on purely negative evidence. In the South of India the great series of basic dykes which break through the old crystalline rocks, and sometimes through the Dharwars, have, partly from their being grouped around the Cuddapah area,[1] and partly from their absence from the younger Karnul strata, been generally regarded as the dyke-representatives of the great lava-flows in the Chey-air group of the Cuddapah system. It is interesting to find that this evidence, which alone would be very unsatisfactory, receives confirm-

[1] *Cf.* Manual Geology of India, 2nd Ed, p. 40.

ation by comparison of the petrological characters of the dykes and the lava-flows, which agree not only in the ordinary characters, but in exhibiting certain peculiar features rarely exhibited in other areas.

III.—CLASSIFICATION OF THE ROCKS.

4. So far as represented by specimens in the Calcutta collection, the dyke-rocks of South India and the lava-flows in the Cuddapahs, their supposed volcanic representatives, belong to three main groups, which pass into one another by a series of transitional types too gradual to permit of any definite line of demarcation. For convenience of description they are classified as follows:—

(1) OLIVINE-NORITE GROUP, in which olivine, enstatite, augite and a basic plagioclase-felspar are essential constituents, the plagioclase being always the latest constituent to complete its consolidation and enveloping all its associates. Small quantities of biotite are invariably present.

(2) AUGITE-NORITE GROUP, distinguished from group 1 by the absence of olivine, and by an increase in the amount of augite. The plagioclase is still the latest constituent to complete its consolidation. Biotite in small quantities is generally present.

(3) AUGITE-DIORITE GROUP, in which the enstatite is either small in quantity or absent altogether. Biotite at the same time disappears, and the order of consolidation of the constituents is modified, giving rise, by the later comparative consolidation of the augite, to a tendency to the production of ophitic structure. The members of this group are invariably characterised by the presence of micropegmatitic (micrographic) intergrowths of quartz and felspar, which are regarded as primary in origin, and sometimes contain potash-felspar.

5. The following table gives the order of consolidation of the essential constituents in each group:

1. Olivine-norite group.	2. Augite-norite group.	3. Augite-diorite group.
Olivine.	...	...
Enstatite.	Enstatite.	...
Augite.	Augite.	Augite.
Plagioclase.	Plagioclase.	Plagioclase.
...	...	Micropegmatite.

Hemicrystalline representatives.

6. Each group is represented by *microcrystalline* and *hemicrystalline* types occurring either as thin veins, or as selvages to larger masses.

Group 1 is represented (1) by a rock having a black cryptocrystalline matrix with phenocrysts of *olivine only* and (2) by a micro-variolitic tachylyte.[1]

Group 2 is represented by a micro-crystalline matrix of augite, felspar and magnetite with some glass, in which there are phenocrysts of *enstatite only*.

Group 3 is represented by a microcrystalline matrix of augite, felspar and magnetite with phenocrysts of augite and labradorite.

The hemicrystalline varieties of groups 1 and 2 are thus related to the comparatively rare magma-basalts (*limburgites*) in which the essential phenocrysts are olivine and augite; but as the Madras rocks show in one case only olivine and in other cases only enstatite, they differ, as far as I am aware, from any previously-described type; but, until their field-relations have been more precisely traced out, I consider it inadvisable to distinguish them by special names.

The chemical analyses of these rocks by Mr. Brühl (see paragraphs 10, 22, 49 and 71) show that they vary in silica percentage from 43·77 to 53·05; but the variation in silica percentage is by no means as uniform as that of the magnesia which varies from 21·21 per cent. in the Jootoor lava-flow to 6·48 in the augite-diorite dykes.

(1) OLIVINE-NORITE GROUP.

(*a*.) *Holocrystalline varieties.*

7. Amongst the great lava-flows of the Chey-air beds described in his memoir "On the Kadapah and Karnúl formations in the Madras Presidency," Dr. W. King has referred to the Jootoor flow on the left bank of the Pennair river as an olivine-bearing rock.[2] Mr. P. Lake, in a paper on "The Basic Eruptive Rocks of the Kadapah Area," described the microscopic characters of this rock as an olivine-dolerite or olivine-gabbro, composed chiefly of olivine, augite, and plagioclase felspar, "with opacite" and a little mica.[3]

[1] Since the above was written, Mr. C. S. Middlemiss has called my attention to a hemicrystalline representative of this class collected by him at a place 1½ miles. E.N.E. of Kanivenhalli, near Palakod, Salem district (No. 10,262). The rock occurs as a dyke only 8 inches wide, cutting obliquely across the gneiss. It is very compact and dark-grey in colour, weathering into round boulders. Microscopic examination shows it to be an *enstatite magma-basalt* (enstatite limburgite); that is, a magma-basalt in which, besides augite and olivine, there are phenocrysts of enstatite; indeed enstatite is the most abundant member of the phenocrystalline constituents. The characters of the mineral are precisely those of the enstatite occurring in the peculiar "norite-felsite" of Eriyúr (para. 48) and the likeness is rendered still more striking by the shells of augite in which the enstatites are so remarkably encased. The groundmass, composed of minute augites, skeleton crystals of magnetite and small quantities of possibly embryonic felspars, also recalls the finest-grained varieties of the Eriyúr rock; but the fine phenocrysts of the peculiar brown olivine found in the rocks from Singapuram (para. 25), Vitlapuram (para. 33) and Coonoor (para. 36) connect this interesting rock with the class of olivine-norites Besides being of value as a means of additional evidence showing the relationship between the olivine-norites and augite-norites forming these dykes, this rock is interesting as the first-recorded magma-basalt in India, and is one which, on account of its display of enstatite phenocrysts, is a peculiar form of its class.

[2] *Mem. Geol. Surv. Ind.*, Vol. VIII, p. 196 (1872).

[3] *Rec. Geol. Surv. Ind.*, Vol. XXIII, p. 259 (1890).

8. Further examination of the rock, however, shows according to my determination that the predominating pyroxenic constituent is enstatite, whilst the plagioclastic felspar, which is very small in quantity, occurs as the last-formed constituent growing ophitically around its associates, olivine, enstatite and augite. In addition to these facts, there are certain peculiar structures which strongly recall those exhibited in many of the rocks occurring as dykes amongst the crystalline rocks of South India, and still more strikingly a handsome rock recently collected by my colleague Mr. P. N. Datta in South Rewa (Rock number 10,588).

As the last-named rock is the most coarsely-crystallized, and the freshest specimen in the group now under consideration, it may be conveniently selected as the type for detailed description.

9. The rock occurs, according to Mr. Datta, as a dyke in mica-gneiss on the Sone River, one mile south-west of Kaithaha, near Saria, South Rewa (lat. 24° 11·5', long. 81° 23'). In hand-specimen it is a dark-coloured, tough rock, with flakes of brown mica, granules of olivine and cleavage-plates of felspar distinctly visible to the naked eye. Its specific gravity is 3·47.

10. A chemical analysis (*cf.* para. 22) made by Mr. Paul Brühl, Professor of Physics in the Civil Engineering College, Sibpur, gave the following results :—

$Si\ O_2$	50·45
$Ti\ O_2$	0·63
$Al_2\ O^3$ (with a small quantity of P_2O_5 and Mn_3O_4)	6·50
$Fe_2\ O_3$	2·49
$Fe\ O$	8·38
$Ca\ O$	7·82
$Mg\ O$	19·02
$H_2\ O$	0·97
Alkalies	undetermined.

11. Under the microscope the rock is seen to be a holocrystalline aggregate of the following minerals, whose names are given approximately in the order of their formation :—

Primary :—
- Apatite.
- Olivine.
- Enstatite and Augite.
- Biotite.
- Plagioclase.

Secondary :—
- Reaction rims of actinolite and enstatite.
- Biotite.
- Magnetite.

12. *Apatite.*—Occurs only in small quantities, with the usual needle-shaped prisms cracked transversly, showing low double refraction, and included by all the other constituents except olivine.

13. *Olivine* occurs in large crystals, generally with their idiomorphic outlines well displayed. They are cracked in the characteristically irregular fashion with the development of much dusty magnetite. Besides innumerable, small, rod-like inclusions arranged in parallel lines, the dendritic inclusions which have been described by Professor Judd[1] as one of the results of the schillerization of this mineral are

[1] *Quart. Journ. Geol. Soc.*, Vol. XLI, p. 381 and plate XII, figs. 2-7 (1885).

very beautifully displayed in this mineral, and are arranged parallel to the macro-pinacoid, as I have shown to be the case in the olivines of a mica-hypersthene peridotite occurring in the Mánbhúm district of Bengal.[1] This is very clearly demonstrated in one of the sections (No. 2125) evidently cut parallel to the basal plane, and showing the cut edges of the dendritic plates lying at right angles to the brachy-pinacoidal cleavage cracks. The quartz wedge inserted parallel to the edges of the inclusions shows well-marked 'thinning' thus indicating the axis of maximum elasticity $\mathfrak{a}$ parallel to the macro-diagonal.

"Reaction-rims."

14. But the most striking feature in connection with these olivines is the occurrence of very well defined and broad "reaction-rims" between this mineral and the felspar, similar to those which have so frequently been recorded in basic and ultra-basic rocks. The reaction-rims are composed of an external layer of feathery green actinolite abutting against the felspar, considerably wider, as a rule, than the inner zone of granular, colourless mineral, which exhibits a double refraction distinctly lower than that of the actinolite.

The colourless mineral in this case is regarded as enstatite, because it has been found in several instances in crystallographic continuity with larger adjoining original crystals of that mineral. It is frequently found also that both the augites and the enstatites are separated from the olivine by a very narrow zone of this colourless mineral, which sometimes exhibits crystallographic continuity with the enstatite, appearing thus as a secondary extension of the mineral, like the well known secondary enlargements of quartz, felspar, augite, hornblende and mica (Fig. 1).

15. The question of the origin of these so-called reaction-rims which so frequently characterise the olivines of very basic rocks has frequently been discussed, and very different explanations have been offered, both as to the precise nature of the reaction products and the mode of their formation, which is not a surprising result, seeing both the compositions of the reacting minerals, as well as the physical conditions of formation must, within certain limits, be variable.[2] Although the present instances do not appear to offer conclusive evidence, the general assemblage of facts point, in my opinion, to the origin of the rim as the result of the reaction between the olivine and a more siliceous mineral, felspar, under the particular physical conditions which are attended with various other structural characters—primary and secondary—that distinguish plutonic rocks from lavas. In this case the reaction-rims occur in a rock which shows the schillerization and other phenomena characteristic of deep-seated rock-masses, whilst all these structures are absent in the Jootoor lava, which mineralogically is the very evident equivalent of this rock. But in the lava a pilitic decomposition of the olivine has taken place (*vide infra* para. 23) which is certainly secondary and confined by the original limits of the olivine crystals. The evidence points also to the formation of the pilite with the aid of compounds derived from the adjoining decomposing felspar.

16. That the fibrous and granular borders are real reaction-rims is therefore

[1] *Rec. Geol. Surv. Ind.*, Vol. XXVII, p. 144 (1894).

[2] For summary of results see J. F. Kemp "Gabbros on the western shore of Lake Champlain" [*Bull. Geol. Soc. of America*, Vol. V, p. 221 (1894)], and a later paper in the same year by W. D. Mathew on "The intrusive rocks near St. John, New Brunswick" [*Trans. N. Y. Acad. Sci.*, Vol. XIII, p. 198, (1894)]. In the latter paper the author points out the continuity of the granular inner zone with larger hypersthene crystals and regards it as an original formation.

supported indirectly by the peculiar nature of the secondary decomposition of the olivine in the lavas; but the question as to whether the reaction-rims are formed during the consolidation of the rock—as the late G. H. Williams supposed to be the case in the very similar and now well-known occurrence near Peekskill, N.Y.—,[1] or subsequently, is not determined by this evidence, as there are so many instances to show that the structures produced rapidly during the primary consolidation of a molten magma can be closely imitated by those produced more slowly during secondary changes subsequently induced in the consolidated rock.

17. The *pyroxenes* are nearly all colourless, the rhombic forms exhibiting a faint pleochroism only in thick sections. The most abundant form is enstatite, which exhibits in part at least its proper crystal outlines, with characteristic cleavage and optical characters.

18. The most remarkable feature in connection with the pyroxenes is the development of a series of minute and vermiform canals, arranged in approximately parallel directions and giving an appearance which at first sight resembles the micropertthitic structures of felspars. Sometimes patches of such structures are seen spreading out like a disease in the pyroxene, and changing its polarization colours to a lower order. Isolated patches sometimes show simultaneous extinction, and at other times the patches growing out from different points in a pyroxene crystal meet in irregular lines and divide the crystal into a mosaic between crossed Nicols. This may occur either in a rhombic or a monoclinic pyroxene, but the ragged portions exhibit colours of too high an order for the rhombic form. Although I feel unable to account satisfactorily for this phenomenon, the microscopic intergrowth of two pyroxenes seems to meet all the requirements of the case more perfectly than any other explanation that has occurred to me. Whatever the structure may be due to, it is found again in just as striking a manner, though less frequently, in the Jootoor trap-flow, whose characters generally so closely repeat the microscopic structures and mineralogical composition of this rock.[2] Like all the primary constituents of this rock, the pyroxenes are schillerized, and more strikingly so in the monoclinic than in the rhombic forms.

19. The *felspar*, which is the least abundant and last formed amongst the primary constituents, is twinned in broad lamellæ and exhibits wide extinction angles approaching those of bytownite. It is often darkened by fine dusty inclusions and the high powers show numerous minute needles and plates arranged in parallel lines, as is commonly the case with schillerized plagioclase.

20. *Biotite* occurs as minute plates intergrown with the enstatite in a way which suggests its derivation from the latter mineral. It occurs also in larger bundles which exhibit a strong pleochroism and contain numerous dark-brown needles crossing one another as usual at angles of 60°. The biotites are certainly of later

[1] *Amer. Journ. Sci.*, 3rd ser., Vol. XXXI, p. 35 (1886).

[2] This structure resembles in many respects those which have been described and figured by Prof. Sollas in the gabbro of Barnavave, Carlingford, and which he ascribed to an intergrowth of diallage and rhombic pyroxene which are intergrown so that the face 010 of one lies parallel to the face 100 of the other (*Trans. Roy. Irish Acad.*, Vol. XXX (1894), p. 484; plate XXVI, figs. 4 and 6). But in the rock under description the intergrown pyroxenes appear to be invariably both monoclinic, though intergrowths of a different nature of both monoclinic and rhombic pyroxenes are also found in this rock.

formation than the pyroxenes which they frequently partly envelope, but are, however, older than the felspars.

21. A rock having precisely similar mineralogical composition, and equally fresh, has been collected by Mr. R. Bruce Foote at Kudatami in the Bellary district, No. 8,767. The order of consolidation of the constituents is precisely the same also as in the Rewa rock; but there is no trace of a reaction-rim between the olivines and felspars, and in this rock the olivines are the only constituents showing signs of schillerization. These facts so far as they go, therefore, are in agreement with the suggestion that schillerization and the formation of reaction-rims imply in some respects at least similarity of physical conditions (*supra*, para. 15). Professor Judd[1] has included the formation of reaction-rims amongst the instances of secondary changes induced in rocks under the combined influence of pressure and high temperature, and the facts revealed by the examples under consideration are, so far as they go, in agreement with such a conclusion.

Comparison with the Jootoor lava.

22. On comparing this rock with the *Jootoor trap-flow* (No. 9,793), we find the differences are almost entirely due to a more fine-grained crystallization and the absence of schillerization phenomena in the latter rock. These are just such differences as might be expected between a plutonic rock and its volcanic representative. The essential constituents and the order of their formation—olivine, colourless enstatite and augite, biotite and plagioclase—are identical. The proportion of felspar, however, is smaller, and olivine is more abundant, but the minerals are apparently of the same species and even the peculiar micrographic structure shown by the pyroxene of the Rewa rock is exhibited also, though less frequently, in the Jootoor lava.

These differences in the proportions of mineral constituents bringing the rock into close relations with the saxonites (harzburgites), appear in the chemical analysis made by Mr. P. Brühl, which gave the following results (*cf.* para. 10).

$Si O_2$ . . .	43·77
$Ti O_2$ . . .	0·74
$Al_2 O_3$ (and $P_2 O_5$) .	7·53
$Fe_2 O_3$ . . .	4·64
$Mn_2 O_3$ . . .	0·74
$Fe O$ . . .	7·91
$Ca O$ . . .	5·58
$Mg O$ . . .	21·21
$H_2 O$ . . .	3·15
Alkalies . . .	undetermined.

Pilite.

23. The original outlines of the olivines in this rock are marked by lines of opaque black granules, between which and the core of undecomposed olivine there is a zone of variable width of a fibrous mineral exhibiting low double refraction and forming generally a confused felt. As this zone of fibrous mineral is well-developed at the contact of the olivine with felspar, and is practically absent where the former mineral abuts against either of the pyroxenic constituents, it is evident that proximity to the felspar facilitates the formation of the fibrous mineral. The lines of opaque granules, from their rectilinear disposition, evidently mark the original outline of the olivine crystals,

[1] *Journ. Chem. Soc.*, May 1890.

and thus the fibrous mineral must have been formed entirely at the expense of the olivine.

24. These zones are, therefore, secondary in origin, and as they do not extend beyond the limits of the original olivine-crystals, they cannot be regarded as the equivalents of the reaction-rims so beautifully displayed by the Rewa rock. The fibrous area is very variable in width, sometimes extending to the centres of even large crystals of olivine. The features exhibited agree with those of a fibrous form of amphibole and are probably similar to the felt of amphibole needles pseudomorphous after olivine to which Becke has given the name *pilite*.[1] As the felspars are often considerably kaolinized, it is not unnatural that this change to amphibole (pilite) should be more marked where the olivine is bordered by the mineral whose decomposition can supply the requisite amount of lime and silica.

Olivine-bearing dykes of Madras (Salem district).

25. Amongst the *dykes* occurring in the Madras Presidency the nearest approach to the rocks of the class under consideration occurs near the quartz-magnetite beds of Singapuram, Ahtur taluk, Salem district (No. 9,398). This rock is black in hand-specimen even to the felspars, which show slight "lustre mottling." It has a specific gravity of 3·12. Under the microscope it is seen to be perfectly holocrystalline in structure and is composed of olivine, enstatite (bronzite and hypersthene), augite, biotite and plagioclase in order of formation, with granules of pyrite and dusty magnetite.

26. The *olivine* is about equal to the pyroxene in quantity; it often shows its crystal outlines, but is rarely intergrown with the enstatite to produce a very imperfect graphic structure. It is cracked in a characteristically irregular fashion, with separation of dusty magnetite and very rarely shows the serpentinous hydration. Reaction rims between it and the felspar occasionally occur, but are generally very narrow though very well-defined, and with the same arrangement of colourless mineral and actinolite as seen in the Rewa rock.

27. The most characteristic feature of the olivine, however, is the large quantity of minute inclusions—dust and rods—arranged in definite crystallographic planes and giving the sections a brown or dark brown colour when seen with low powers, and what, on rapid revolution of the polariser, appears to resemble the faint pleochroism of some brown augites, but which is probably only a diffraction effect. This character is true of the olivines in all the dyke-rocks which I have mentioned below and which I propose to include in this group The general characters exhibited by the sections of this mineral leave little doubt as to the nature of the species, and that little doubt is completely removed by the occurrence in this rock of the dendritic inclusions such as are so plainly displayed in the olivines of the Rewa rock (slide 1424).

28. The *enstatites* show a distinct pleochroism, sometimes approaching in intensity that of the hypersthenes which are constant throughout the pyroxene granulites of this area.

29. The *augite* is perfectly colourless in thin section, is feebly schillerized and frequently developed between the felspar plates like little intrusive sheets and fingers, which, when cut across, show several isolated patches having simultaneous extinction.

[1] *Tschermak's min. und petr. Mitt.*, Vol. V, p. 163 (1883).

30. The *biotite* is frequently associated with coarse granules of opaque iron-ores, shows the same kind of pleochroism, and occurs in apparently the same proportions as already described for the Rewa rock and the Jootoor lava.

31. The *felspar* is more abundant and of a less basic type than that playing a similar rôle in the Rewa rock. The crystals are light-brown in section on account of innumerable minute inclusions, but the colour shades off towards the periphery of the crystals which are generally colourless. Polarized light shows also that there is a zoning due to gradual change in composition in the later-formed layers. Minute acicular inclusions, like actinolite-needles, are often seen in patches of the colourless portion of the felspar, where there appears to have been a small amount of decomposition with sometimes formation of presumably secondary quartz.

32. *Magnetite* in fair quantity occurs in all the other minerals, either as lumps, which are possibly original, or as fine dust, which is of secondary origin. Occasional lumps of *pyrite* are seen in hand-specimen.

South Arcot district.

33. For the next stage, showing a less basic tendency, a rock collected by Dr. H. Warth at one mile west of Vitlapuram in South Arcot district, may be taken as a type (No. 9,811). This rock occurs as a dyke in the pyroxene-granulites, most of which in that area contain large quantities of quartz, and are distinctly acid in silica-percentage.

34. The dyke-rock is black in hand-specimen, and has a specific gravity of 3·03 (Warth). Under the microscope, it shows the same peculiar dark-brown olivine, colourless enstatite and augite, small quantities of biotite, magnetite and pyrite, and the same brown, zoned plagioclase with colourless borders, forming the groundmass as in the Singapuram rock. But in the Vitlapuram rock there is a distinctly smaller quantity of olivine, and, at the same time, an increase in the size and frequency of the colourless patches, which shows the signs of secondary decomposition referred to before, but in this case calcite as well as quartz occurs amongst the secondary minerals.

35. The Singapuram rock occurs at a place which is about equidistant from Vitlapuram near the Coromandel coast and Coonoor in the Nilgiri Hills (a total horizontal distance of about 200 miles), where I have also found dykes of unmistakably the same rock intrusive in the pyroxene-granulite series which make up the main mass of that range.

The Nilgiris.

36. The dykes of Coonoor are especially interesting on account of the variations they show from the well-crystallized types in the wider dykes to the hemicrystalline and even glassy tachylytic types which occur in the narrower veins and on the selvages of larger masses, but in all of them the peculiar brown olivine occurs, and the same order of crystallization of the pyroxenes, biotite and light-brown plagioclase-felspar is preserved. Although the plagioclase crystals are seen to be the last-formed from the way in which they are moulded on to all the other constituents, their crystallization, having commenced from so many centres during the comparatively rapid consolidation of the final stages, has not resulted in their perfect ophitic development, as is the case with the coarser-grained types described from the other localities above.

37. In the very fine-grained varieties forming narrow veins in the pyroxene-granulites, the microscope shows olivine, pyroxene and felspar as phenocrysts in a microcrystalline matrix of pyroxene, biotite, felspar and magnetite, and the pheno-

crysts sometimes gather in groups giving rise to the structure to which Prof. Judd has given the name *glomero-porphyritic*.[1] This sometimes takes the peculiar form of large olivine crystals surrounded by a zone of colourless granular pyroxene (slide 1599). In the narrow veins the long crystals of felspar and enstatite are frequently arranged parallel to the sides of the dyke, a feature commonly exhibited by porphyritic crystals in narrow dyke-rocks.

Variolitic selvages.

38. As the edge of the dyke is approached the matrix becomes finer in grain, until, at the selvages, the rock shows a vitreous matrix with tufted aggregates of microlites, attempting an imperfect spherulitic or variolitic structure. Glomero-porphyritic aggregates of olivine and enstatite occur as in the types described above.

(*b*.) *Exceptional hemicrystalline varieties of olivine-norites.*

39. An exceptional type of the hemicrystalline varieties which presumably belongs to this class of rock occurs as a narrow vein only half an inch wide running through a hornblende-norite collected by the late Mr. C. Æ Oldham near Poorsy, N. N. W. of Wandiwash.

Magma-basalt without augite.[2]

This rock consists of a matrix blackened by magnetite-dust, and studded with excessively minute, colourless microlites, in which occur well-shaped phenocrysts of olivine reaching 3 mm. in length and cracked in the usually irregular fashion of olivine with slight development of yellow serpentine.

40. The *olivines* show a very striking zonal structure by the alternations of light-brown and colourless bands, which however are sometimes quite irregular in arrangement. The light-brown patches display a very faint pleochroism, which is only noticeably marked in basal sections, and shows an absorption in those sections of $\mathfrak{a} > \mathfrak{c}$ (slide No. 2027). In those sections also minute rod-like inclusions are arranged at right angles to the brachypinacoidal cleavage-cracks and evidently are the results of the normal schillerization of the mineral (*vide supra*, para. 13).

The last stages in the growth of the crystal are marked by layers of opaque granules, and the colourless zone separating this layer of granules from the opaque matrix is frequently decomposed and pilitic, in which cases the layer of opaque granules has generally a ragged inner border due to extension inwards of the decomposition, accompanied by the usual separation of dusty magnetite. The mineral is decomposed by strong hot hydrochloric acid with formation of gelatinous silica. The crystals are frequently corroded by the magma (Plate I, fig. 3).

41. The occurrence of olivine so well-developed and as the only phenocrystalline constituent makes this a most unusual type of rock. *Magma-basalts* (*limburgites*) with augite as well as olivine phenocrysts have been described from various places, and, to a less extent, *augitites* with augite only developed; but I can recall no case exactly parallel to this in which well-formed olivine in a black glassy matrix is the only phenocryst.

(*c*.) *Association of Olivine-norites with "Pyroxene-granulites."*

42. If, as seems very likely from their close resemblance to the Jootoor lava-flow, the dyke-rocks described above are the plutonic equivalents of the volcanic

[1] *Quart. Journ. Geol. Soc.*, Vol. XLII, p. 71 (1886).

[2] Mr. C. S. Middlemiss has, since the above was written, called my attention to a fine example of an enstatite magma-basalt amongst these dykes. For its description see para. 6, foot-note.

rocks of the Cuddapah system, the time of their intrusion is fixed with regard to the Indian stratigraphical succession.

43. That these rocks are true intrusions and not segregation veins is very evident from their occurrence as vitreous forms near the selvages of larger dykes and in the smaller veins, with fluidal structures also. As they break across the pyroxene-granulite series of the Madras Presidency, showing no signs of the foliation which the latter rocks have suffered, their intrusion must have occurred since the foliation of those rocks. And yet there remains the remarkable fact that rhombic pyroxene, which is the one constant constituent of the pyroxene-granulite group, is present in all these dykes which are so frequently associated with them. That this is a mere accident is of course quite possible; still, the association is a circumstance worthy of record, and I give it as a mere suggestion that the magma from which these intrusions and lavas have been derived might have been obtained by the local re-fusion of the pyroxene-granulite series.

44. The association of olivine-norites with the ordinary members of this group has been recorded in different parts of the world; but the cases presenting the nearest approach to the instance under consideration are the rocks of the Cortlandt series of New York, in which the late G. H. Williams[1] described types varying from peridotites with little or no felspar to normal norites, and those described by Dr. F. H. Hatch[2] from Madagascar, where olivine-norites are associated with ordinary types which are remarkably similar to those of the Madras Presidency, and are probably simply a portion of the same great crystalline mass —portions of the old Gondwana continent still remaining above the sea-level.

The chemical analyses by Mr. Brühl of four different Madras types show that alumina is comparatively low amongst the sesquioxides, whilst magnesia and ferrous oxide are unusually abundant amongst the protoxides, results which might be expected where the ordinary augites are so largely replaced by enstatites amongst the ferromagnesian silicates. It will be interesting to compare these analyses with those now being made of the various types of the pyroxene-granulite series of the Madras Presidency.

(2) AUGITE-NORITE GROUP.

(*a.*) *Holocrystalline varieties.*[3]

45. As examples of dykes linking the characters of the olivine and enstatite-bearing group with those in which augite predominates, may be mentioned those discovered near Rayakotta, Maharajgadi, and Krishnagiri in the Salem district, by my colleagues Messrs. Middlemiss and Smith, who have kindly sent me specimens and descriptions of the field-relations and microscopic characters of the rocks.

46. The most striking of these occurs as a dyke 100 yards wide running east and west in the gneiss, 5 miles south of Vepanapalli, on the road north of Krishnagiri.[4] It has a specific gravity of 3·08 and is composed, according to Mr. Smith, of idiomorphic crystals of hypersthene, a smaller quantity of augite, wrapped around

[1] *Amer. Journ. Sci.*, 3rd ser., Vol. XXXI (1886), p. 26; Vol. XXXIII (1887), pp. 135—191.

[2] *Quart. Journ. Geol. Soc.*, Vol. XLV (1889), p. 342. *Cf.* R. Baron, *ibid.*, Vol. LI (1895), p. 59.

[3] For varieties approaching pyroxenites by diminution of felspar see para. 56.

[4] Field number (A) 11th February 1896.

by large ophitic-like plates of plagioclase. As accessories, in part secondary in origin, are biotite, hornblende and magnetite-granules. In the specimen sent I have also found crystals of clear quartz, which, being associated with the kaolinized portions of the felspar, are possibly of secondary origin. This rock differs from the previously-described group, therefore, only in the absence of olivine, whilst the presence of a rhombic as well as monoclinic pyroxene, and the order of consolidation of the constituents make it a link on the basic (olivine-bearing) side.

47. A second link is represented by some small dykes in the gneiss south of Bolconda on the Salagiri-Krishnagiri road in the same district.[1]

In this rock Mr. Smith finds the hypersthene and augite to be represented in about equal quantities, and the specimen sent shows some interesting intergrowths of the two minerals.

(*b.*) *Exceptional hemicrystalline variation of Augite-norites.*

48. The rocks of this transitional group are represented also by hemicrystalline varieties which are of a most unusual type. Specimens of these have been collected by Dr. Warth near Eriyur in the South Arcot District (No. 9,782).

They are tough, black, tachylytic-looking rocks, with small glassy-looking crystals of a colourless mineral, which, under the microscope, are seen to be enstatite, lying in a fine-grained, black matrix, which is probably in part vitreous. This rock corresponds in this group to the Poorsy rock in the olivine-norite group and to the augitites which have been described in various parts of the world. But both this and the olivine-bearing rock of Poorsy are, so far as I am aware, type hitherto undescribed.

49. It occurs, according to Dr. Warth, as a dyke four feet wide running east-north-east and west-south-west in the pyroxene-granulites, and specimens gave an average specific gravity of 3·09.

An analysis of this peculiar rock by Mr. P. Brühl gave the following results:—

SiO_2 . . .	53·05
TiO_2 . . .	1·77
P_2O_5 . . .	0·09
Al_2O_3 . . .	8·91
Fe_2O_3 . . .	3·26
Mn_2O_3 . . .	0·09
FeO . . .	9·52
CaO . . .	6·76
MgO . . .	14·42
K_2O . . .	0·48
Na_2O . . .	0·66
H_2O . . .	0·65
	99·66

50. Under the microscope well-shaped crystals of *enstatite* attaining 2 mm. in length form the only phenocrysts. They are perfectly fresh and colourless, and from the shapes of the sections which show the typical cleavage of pyroxene, exhibit combinations

The Enstatite phenocrysts.

[1] Field number (A) 6th February 1896.

of the two pinacoids with the prism, giving the eight-sided shapes so commonly displayed by horizontal sections of pyroxenes. They exhibit a tendency to aggregate in groups of several individuals. The double refraction is low, and the two optic axes can be distinctly observed in basal sections examined by convergent polarized light. The crystals are unattacked by hot hydrochloric acid.

The groundmass.

51. The groundmass of the rocks consists of minute crystals of colourless augite wrapped around by tufted microlites of presumably felspar, with a black opaque glass (?) filling the interspaces.

Augite microlites.

52. The colourless crystals, though so minute, are well-defined, and their examination with $\frac{1}{8}$-inch objective leaves no doubt about their being augite. They exhibit a tendency to form long crystals with the prismatic faces well developed, and are often very clearly twinned according to the usual law of augite. Well defined cleavage-cracks are displayed by the larger individuals. Groups of apparently isolated crystals often show simultaneous extinction. Their strong double refraction and wide extinction angles serve to distinguish them from the large phenocrysts of the rhombic pyroxene.

Intergrowths of rhombic and monoclinic pyroxenes.

53. The tendency they exhibit of growing around the phenocrysts of enstatite is a feature of special interest on account of its bearing on the frequent intergrowths of these two minerals, which are described below (para. 60). In most cases the augite sections are seen like two long lath-shaped crystals on either side of the vertical sections of enstatite, but instead of being sections of independent crystals they are found invariably to exhibit simultaneous extinction. As the lath-shaped crystals bordering the sides of the enstatites are frequently found in optical continuity with a narrow band around the ends of the latter mineral, there is no doubt that the enstatite is encased in a thin shell of augite, which belongs to one crystal and though in this rock is invariably so thin, it represents the beginnings of the large crystals described below (para. 60). In addition to this casing of the enstatite in augite, which is quite common, numerous cases occur in which minute pieces of the latter mineral are found scattered through the phenocrysts of the former, and all show by simultaneous extinctions the crystallographic continuity of these included fragments of augite with the thin casing of the same mineral, and thus we have the beginnings of the complicated intergrowths of the two forms of pyroxene so frequently recorded in the basic rocks.

Felspar microlites.

54. The colourless tufted microlites, which, with minute opaque black granules, constitute the rest of the groundmass, belong presumably to the felspar which plays the rôle of groundmass in the holocrystalline types of these rocks. They show weak double refraction and extinction angles of about 10° measured from the long axis of the microlite, and binary twins could be distinctly observed. In this rock therefore we have the order of consolidation the same as that shown in the holocrystalline forms—enstatite, augite and felspar.

As this rock changes considerably in grain even in the same hand-specimen it would be interesting to trace out the characters of the dyke more precisely. But, so far as the specimens collected by Dr. Warth go, the coarser-grained portions show a very striking approach in their characters to those of the more holocrystalline type found by Mr. Middlemiss in the Salem district and described below (para. 56).

(c.) *Volcanic representatives of the Augite-norites.*

55. As far as can be determined with the small amount of material available for comparison, the Palamodu trap-flow (No. 9,794) of the Cuddapahs appears to correspond in mineralogical character to the dyke-rocks included in this group. Mr. Lake[1] has described this rock, calling attention, amongst other results of its secondary decomposition, to the presence in it of bastite, which he regards as the result of the alteration of the augite. From the way in which this mineral is associated with the augite I should suggest that it is the altered representative of the enstatite which, in the fresher dyke-rocks, shows a precisely similar relation to the augite, and is unquestionably an original constituent. The alteration of the less stable enstatite which shows such ragged irregular junction with the augite in the fresh rock might very well give rise to the impression that it is the result of change extending outwards from the centres of the latter mineral. It should be remarked, however, that the ophitic structure shown so strongly in this rock distinguishes it from the members of the augite-norite group in which the pyroxene shows such a tendency to crystallize before the felspar. I do not, consequently, put much reliance on this correlation. It is unfortunate that the great trap-flows of the Cuddapahs, which evidently include an interesting variety of rocks, should be represented by so few specimens, and until further collections are made the correlation of the dykes with the lava-flows must remain in its present rather unsatisfactory state.

(d.) *Varieties approaching Pyroxenites.*

56. It is frequently found that in the foregoing two groups the rocks locally approach the ultra-basic group by diminution in the proportion of felspar. In the olivine-bearing group, for instance, the rocks sometimes approach saxonites (harzburgites) in composition, and in this group pyroxenites. An interesting example of the latter modification has been found by Mr. Middlemiss two miles from Thalli on the Hosur road, Salem district.[2] Mr. Middlemiss describes the rock as a dark, greenish-grey, medium grained rock with a specific gravity of 3·11. Under the microscope it is composed of enstatite in large idiomorphic crystals, augite in smaller granular crystals, often grown around the enstatite, and plagioclase in long slender blades arranged in branching and net-like fasciculæ or tufts. These sometimes run around, and sometimes end abruptly against, the pyroxenes, appearing again on the other side. Black iron-ores and a green mineral in small quantity appear filling in spaces between branching felspars. Mr. Middlemiss has kindly sent me a specimen of this rock, and, as his description would lead one to expect, the rock is just such an one as might be expected from the more perfect crystallization of that which I have just described as a hemicrystalline type of this group (paras. 48—54).

57. A still nearer approach to the purer pyroxene-rock, and a type much coarser in grain, was obtained in the year 1889 by Mr. R. Bruce Foote south of Nilgunda, Harapanhalli taluk, Bellary district (No. 8,823). It is a tough, dark grey, even-grained rock with a specific gravity of 3·22. Under the microscope it is

[1] *Rec. Geol. Surv. Ind.*, Vol. XXIII (1890), p. 260.
[2] Field number (1) 12-2-96.

seen to be composed almost wholly of pale *pyroxene*, with the interspaces filled in with a *plagioclase felspar* approaching anorthite in composition, and showing by its extinction a crystallographic continuity in isolated patches over very large areas. The pyroxene is partly pale hypersthene, showing a faint pleochroism and frequently idiomorphic outlines, with a very pale green augite growing around it. The rhombic pyroxene appears to be well in excess of the monoclinic form. Occasional granules of opaque iron-ores occur sometimes associated with biotite. No trace of olivine has been discovered. I have frequently found pyroxenites composed essentially of hypersthene, approaching amblystegite, and augite, sometimes with olivine and pleonaste (hercynite), occurring as masses associated with, and as dykes intrusive in, the norites of the so-called pyroxene-granulite series of Madras; but from the resemblance of these to some forms of the norites in which they occur, I have reserved them for description on another occasion with that group, believing them to be closely related to one another.

(3) AUGITE-DIORITE GROUP.

(*a*.) *Holocrystalline varieties with micropegmatite.*

58. The members of this group are distinguished from those described above, by (1) the predominance of augite amongst the pyroxenic constituents;

(2) a tendency to approach an ophitic structure by an earlier development of the felspar as compared with the pyroxene;

(3) the invariable presence of quartz as a micropegmatitic intergrowth with felspar playing the rôle of groundmass.

These characters are true for a large number of dykes intruded into the gneisses, pyroxene-granulites and Dharwar Transition rocks of the Madras Presidency, as well as of some lava-flows in the Poolumpett beds of the Chey-air group Cuddapah system.[1]

59. The most convenient specimen to introduce this group was collected by myself in September 1893, from a large dyke west of Isa Pallavaram, 11 miles south of Madras city (No. 9,393). It is a black, tough rock with a specific gravity of 3·10. Under the microscope it is seen to be composed of enstatite, augite, opaque iron-ores, biotite and plagioclase with micrographic patches of quartz and felspar. The plagioclase is distinctly the latest constituent to *complete* its crystallization, but it is by no means as distinctly ophitic in character as in the more basic groups already described; but it recalls the structure of some members of the preceding group in the occurrence of blade-like crystals bent around the pyroxenes (*cf.* para. 56). The presence of enstatite in considerable quantities, biotite in small quantities and the late formation of the felspar connect it with the two previous groups, whilst the predominance of augite amongst the pyroxenes and the presence of large quantities of micrographic quartz connect it with the third, and more acid, group of dykes.

60. *Enstatite* was evidently the first mineral to crystallize. It is generally colourless, but sometimes shows a faint pleochroism. It is very frequently surrounded by pale *augite*, whose junction with it can only be detected by polarised light,

[1] For comparison with trap-flows in other Transition systems of Peninsular India, see para. 79.

the cleavage-cracks being continuous, although the augite generally has a brown tint in irregular patches. Between crossed nicols the junction is seen to be very irregular and accompanied by isolated patches of augite scattered through the portions of the enstatite lying near the junction-line, producing complicated intergrowths of the two minerals. The augite generally presents darkened external borders, which are often accompanied by the formation of minute crystals of hornblende and may be a preliminary stage in the process of amphibolization. It is a very common feature in rocks of this type.

For an examination of the characters of the augite a specimen from the Seven Pagodas (No. 9,678) whose bulk analysis is given below (paragraph 71), was selected on account of its being practically free of enstatite. A chemical analysis of separated and carefully picked pyroxene gave the following results :—

$Si O_2$ . .	50·02
$Al_2 O_3$ . . .	5·61
$Fe_2 O_3$ } $Fe O.$ . .	15·61
Mn O . . .	trace
Ca O . . .	14·84
Mg O . . .	12·01
Alkalies . . .	0·96
Loss on ignition .	0·76
	99·81

The augite is thus remarkably similar in chemical composition to that of the monoclinic pyroxene separated by Mr. Teall from the rock of the Whin Sill, whose chemical and microscopical characters so closely resemble those of the augite-diorite dykes in the Madras Presidency. As pointed out by Mr. Teall, the resemblance in chemical composition of this mineral to the rhombic pyroxenes is, in view of the frequent association and intergrowth of augite and enstatite in these rocks, a point of considerable mineralogical interest.[1]

61. The *felspar* is very commonly light brown in the central portions through the inclusion of very fine dust, but the colour becomes less pronounced as the margins of the crystal are approached, and ultimately quite colourless at the margins, where the felspar is frequently intergrown with quartz to produce the micropegmatite which occurs in every member of this group. Between crossed nicols the crystals are seen to be frequently zoned, with the more basic plagioclase forming the centres of the crystals.

62. The *micropegmatite* forms the chief point of interest in connection with these rocks. It occurs as colourless patches in the rock in which minute acicular crystals of actinolite are irregularly disseminated. The characters are so distinct that these patches can easily be detected with ordinary light. The micropegmatite in these rocks evidently represented the colourless patches already noticed in the more basic types (*supra*, paras. 31 and 34), but which only seldom contained quartz.

Primary origin of the micropegmatite.

63. The felspar entering into the composition of the micropegmatite is sometimes crystallographically continuous with the large plagioclase crystals; but in some specimens included in this group microcline occurs.[2] There appears to be no

[1] *Quart. Journ., Geol. Soc.*, Vol. XL (1884), p. 648.

[2] No. 9,795, slide, 2133; No. 9,789, slide, 2131.

reason for regarding this micropegmatite as other than original—the last phase in the consolidation of the rock. The rocks are remarkably fresh and show no signs of the secondary changes which so frequently result in the deposition of pseudomorphous quartz, whilst the felspar is, as already stated, in crystallographic continuity with the larger, unquestionably original crystals.

64. It is an interesting fact that in some cases, where secondary decomposition has just commenced, the micropegmatite patches are always the centres of decomposition (which takes the form of hydration principally), extending to various degrees around, a fact which suggests that these parts of the rock are the portions through which water circulates most freely, possibly because, being the last parts of the rock to consolidate, they are less compact; in fact, on a microscopic scale they may be miarolitic. As a glass generally possesses a lower specific gravity than the same chemical mixture when crystallized, such an occurrence might well be expected where the rock consolidates under limited pressure, and especially where such a strong framework is first produced by the previous consolidation of two intergrown minerals, pyroxene and plagioclase, which make up the principal mass of the rock. These rocks, like most of those in Peninsular India, have been remarkably free from dynamic action since their consolidation; consequently the conditions are most favourable for the preservation of such delicate structures.

Secondary extension of micropegmatite.

65. As it is very likely that this secondary decomposition gives rise to the production of quartz, the micropegmatite may become extended by the formation of quartz in crystallographic continuity with that which was original, and thus a portion of the micropegmatite is secondary in origin. Such an occurrence is well illustrated by a specimen collected by Mr. Middlemiss from a dyke 1¾ miles north of Jaulikerai, Hosur taluk, Salem district.[1] In this rock the felspars have been completely decomposed in the central portions of the micropegmatite, with the formation of green chloritic products which also fringes, with decomposed biotite, the adjoining pyroxenes of the rock. In the same way the felspars are attacked, partly kaolinized, and clear quartz, presumably secondary in origin, is deposited in isolated patches, which are seen between crossed Nicols to be in crystallographic continuity with one another, and form real quartz of corrosion. In a homogeneous matrix, where free development would be possible, one would expect such secondary quartz to exhibit idiomorphic outlines, and such cases have been described and attributed to secondary enlargement of micrographic quartz.[2]

66. Wherever the augite comes in contact with the micropegmatite it shows signs of secondary change with the formation of green hornblende, biotite and concomitant separation of magnetite. The side of the augite away from the micropegmatite and abutting against the ordinary plagioclase generally shows no such signs of alteration. Whether this change in the augite is much later than the formation of the micropegmatite is not certain, but that contact with the latter substance is essential to its production seems certain. These changes in the augite are precisely similar to those which Professor Sollas has described as the result of the *intrusion* of granophyre into augite-diorite ("gabbro") at Barnavave, Carlingford. But in the Madras dykes it is impossible to consider these minute micro-

[1] Field number (4), 13th Feb. 1896.

[2] See *Quart. Journ., Geol. Soc.*, Vol. XLVII. (1891) p. 177.

pegmatitic patches as other than part of the rock and derived from the same magma as the augite and plagioclase.

67. Micropegmatitic intergrowths of quartz and felspar have frequently been described in rocks of this kind. Some of these strikingly resemble the Madras dykes in their mineralogical composition; for example, the "quartz-gabbro" of Carrock Fell, which consists principally of plagioclase and augite, with enstatite often intergrown with the augite, occasional biotite, opaque iron-ores and micrographic intergrowths of quartz and felspar[1]; the "gabbro" of St. David's Head which differs from the Carrock Fell gabbro in containing more biotite and less micropegmatite[2]; the Whin Sill, which shows variations from coarse-grained portions, in which augite becomes idiomorphic, to a hemicrystalline rock near the margins[3]; and the enstatite-diorite of Penmaenmawr,[4] all intrusive in Lower Palæozoic strata.

68. Other examples have been described, but those just mentioned all strikingly resemble the Madras rocks both in mineralogical composition and in structure. The micropegmatite has generally been considered to play the rôle of groundmass and to be the last-formed constituent, but in a paper "On the relation of the Granite to the Gabbro of Barnavave, Carlingford," Professor W. J. Sollas, has described granophyric (micropegmatitic) patches in the gabbro (augite-diorite) and whilst showing that they can always be traced to minute intrusions from the associated acid rocks, suggests that the same explanation may be applied also to such cases as the Penmaenmawr rock and the gabbro of Carrock Fell.[5]

69. For want of evidence, however, as to the occurrence of "granophyres" in association with the Whin Sill, Professor Sollas admits that this explanation cannot be applied to that instance,[6] neither can it be applied to the Madras dykes. Of the large number of dykes which show this structure in Peninsular India, not one, so far as I know, has been crossed by a later intrusion of acid rocks, and even should this happen to be the case, it still remains to be proved that such acid intrusions are not derived from the same magma, and consolidated subsequent to the basic portions as part of one continuous process. I would consequently prefer the explanation which I have already given, namely, that the micropegmatite is really original, the last phase in the consolidation of the rock, and its formation and preservation are facilitated by the perfectly quiet conditions of consolidation and subsequent freedom from dynamic disturbances. The order of consolidation of the minerals in these form a striking illustration of the normal succession according to Lagorio's law, and the formation of micropegmatite by the crystallization of the small quantity of acid mother-liquor after the separation of the basic ferro-magnesian silicates is quite in accordance with this law.

70. If, as I have suggested, the micropegmatite crystallized in the spaces

[1] A Harker, *Quart. Journ. Geol. Soc.*, Vol. L, p. 316 (1894).

[2] A. Harker, Petrology for Students (1895), p. 66.

[3] J. J. H. Teall, *Quart. Journ. Geol. Soc.*, Vol. XL, p. 640 (1884), also *Brit. Petrog.*, p. 207, and plate XIII, fig. 2.

[4] J. J. H. Teall, *Brit. Petrog.*, p. 272, plate XXXV, fig. 2.

[5] *Trans. Roy. Irish Acad.*, Vol. XXX (1894), pp. 487—490.

[6] During the discussion on Mr. Harker's recent paper on the granophyres of Skye, Mr. Watts pointed out that the Whin Sill at Caldron Snout passed into a rock which was practically a gabbro embedded in granophyre.

formed between the strong framework of coarsely-crystallized pyroxene and plagioclase, these microscopic miarolitic cavities were probably in imperfect communication with one another, and in this way they may represent in a sense so-called "contemporaneous" veins. It remains to be seen how far supposed intrusive veins of such rocks as graphic granite and granophyre are simple segregations into fissures, whose production have been facilitated by absence o any greater pressure than the fissured rocks are able to withstand. But this opens a wider question than the rocks under consideration afford data for discussion.[1]

71. Passing on to other members of this group represented in the dykes of South India, we find that the rock of Isa Pallavaram passes gradually into more typical augite-diorites by loss of enstatite and biotite, and by a tendency for the plagioclase to crystallize at an earlier stage, being either contemporaneous with, or even later than, the augite, with a consequent tendency to the production of the ordinary ophitic type of many rocks known as diabases. Good examples of this type have been collected by Dr. Warth at Mailam (No. 9,795), Perumbakam (Nos. 9,789 and 9,790), Tirvukarai (Nos. 9,777 and 9,778), in South Arcot district; and by myself at the Seven Pagodas in Chingelput district (No. 9,678).

The last-mentioned occurrence has given specimens almost free of enstatite, the pyroxene being almost completely monoclinic. An analysis of this rock by Mr. Brühl gave the following results:—

$Si\,O_2$ . . .	51·15
$Ti\,O_2$ . . .	0·44
$P_2\,O_5$ . . .	0·06
$Al_2\,O_3$ . . .	15·92
$Fe_2\,O_3$ . . .	9·34
$Fe\,O$ . . .	2·87
$Mn\,O$ . . .	0·09
$Ca\,O$ . . .	10·40
$Mg\,O$ . . .	6·48
$K_2\,O$ . . .	1·61
$Na_2\,O$ . . .	1·19
$H_2\,O$ . . .	0·11
	99·66

The detection of microcline microscopically (paragraph 63) showing the presence of potash felspar as a constituent of the micropegmatite is confirmed by the comparatively large proportion of potash shown by this analysis. The ratios of silica to sesquioxides and protoxides differ from those of the Whin Sill no more than might be accounted for by the difference in preservation of the two rocks. The Whin Sill has undergone a certain amount of hydrous decomposition, whilst the dyke of augite-diorite at the Seven Pagodas is most remarkably fresh. Both rocks show a striking approach to the hypothetical basic magma of Durocher, which he supposed to contain 51 per cent. of $Si\,O_2$, and possessed a density of 2·96.

[1] Besides the localities already quoted some very fine examples of augite-diorites with micrographic quartz were collected by Mr. Lake during the season 1887-88 in the Bellary district and Raichur Doab, some of them occurring as dykes in the Dharwars:— Nos. 8,537, 550, 552, 558, 569, 592, 612 and 655.

(*b.*) *Hemicrystalline varieties of the Augite-diorties.*

72. As in the two preceding groups, the augite-diorites have their fine-grained and possibly hemicrystalline representatives in narrow dykes and on the selvages of the larger masses. Two of the most striking examples representing each of these conditions have been collected by Dr. Warth. The first was found as a dyke 20 feet wide at Nemeli (No. 9,784), and the second forms the selvage of the large mass of Perumbakam hill (No. 9,788), both in South Arcot district.

Pyroxene-aphanite. (Porphyrite.)

73. In the former case (Nemeli) the pyroxene individuals are frequently found to be rhombic in the centre, exhibiting crystallographic parallelism to the augite growing around. These enstatite cores often show a pair of horns at either end giving the core very much the shape of the crystallites which Mr. Rutley has figured as "crenulites.[1]" The augite is greatly in excess of the enstatite, and although it probably commenced its crystallization before the felspar, these two constituents are sufficiently intergrown to show that they mostly separated simultaneously, leaving a series of spaces which are filled in with skeleton crystals of magnetite and a micrographic intergrowth of probably felspar and quartz on an exceedingly minute scale, in some places what Harker would call *cryptographic*.[2] It would be interesting to follow this rock out to its selvages; but no further specimens were collected.

Augite-andesite.

74. The rock which represents the selvages of the large mass at Perumbakam consists of phenocrysts of augite and olivine in a very fine-grained matrix of probably the same minerals, magnetite and small patches of biotite, forming a closely felted mass in which it is impossible to decide as to the presence of vitreous material. From the specimen alone the rock might very well be described as an augite-andesite.

75. The *phenocrysts* are often gathered into glomero-porphyritic groups showing, by their intergrowths, the approximately simultaneous crystallization of the augite and felspar. These minerals are of the usual type represented in the more perfectly holocrystalline types, and the felspars in the same way are crowded with minute inclusions, giving the crystals a light brown or grey colour. Although with the low powers the pyroxene appears to be almost wholly augite, examination with the high powers shows on a minute scale the microperthite-like structure, which may possibly be due to an intergrowth with rhombic pyroxene.[3]

(*c.*) *Volcanic representatives of the Augite-diorites.*

Bétumcherú lava-flow.

76. Although the contemporaneous lava-flows of the Cuddapahs are represented by a very limited number of specimens in the Geological Museum, those which have been collected strikingly resemble the dyke-rocks already described in mineralogical composition and in structure. Probably the most typical representative of the augite-diorite group is

[1] *Min. Mag.*, Vol. IX, plate, figs. 18, 19 and 20.

[2] Petrology (1895), p. 92.

[3] A similar rock was collected in 1886 by Mr. R. Bruce Foote in the Bellary district and recorded by myself from the hand-specimen as an augite-andesite [No. 9,454; *Rec. Geol. Surv. Ind.*, Vol. XXVII, p. 40 (1894)].

the lava-flow near Bétumcherú, in the Kurnool district, which is a member of the Poolumpett beds of the Chey-air stage, Cuddapah system.

77. Mr. P. Lake[1] has shown that this rock is composed principally of augite and plagioclase with a little magnetite, and has a specific gravity of 3·0. Further examination shows the presence, according to my determination, of considerable quantities of quartz which often forms micrographic intergrowths with the felspar, and a very small quantity of enstatite with occasional flakes of biotite. The relations of the augite to the felspar are precisely those which characterise the augite-diorite group amongst the dyke-rocks, the rock being sub-ophitic. Secondary decomposition has resulted in the partial kaolinization of the plagioclase and in the formation of a microcrystalline chloritic product from the augite.[2]

(*d*.) *Occurrence of augite-diorites with micrographic quartz in other Transition systems.*

78. It is interesting to find very similar augite-diorites with micrographic quartz associated with many of the other Transition systems of Peninsular India which resemble a portion of the Cuddapah system in other lithological characters. Many of these are dykes and consequently cannot be relied upon as evidence for the purposes of stratigraphical correlation; and although the small number of specimens collected from undoubted contemporaneous trap-flows agree very remarkably with the augite-diorites of the Cuddapahs in petrological characters, far more evidence of a precise character is necessary before the characters of the volcanic rocks can be added to the other lithological evidence which forms the only data available for the stratigraphical correlation of these unfossiliferous systems of the Peninsula.

79. Amongst the contemporaneous traps of the Transitions containing micropegmatite which are represented in the Calcutta collection are principally from the Bijawars (Nos. 5,8 and 5,10, which contain olivine and are beautifully ophitic; Nos. 32,126 and 55,34, which have been greatly altered, the latter showing the "herring-bone" structure due to lamellation parallel to the basal plane so frequently noticed by Teall, Harker and others) and the Gwaliors (No. 12·49). The last-named from the Barai trap-flow of the Gwalior Transition series,[3] contains porphyritic crystals of plagioclase, now considerably decomposed.[4]

IV.—SUMMARY OF RESULTS.

80. The dykes intrusive in the gneisses and Dharwar Transition rocks of Southern India, as the well as the Cuddapah lava-flows, which are supposed to be their volcanic representatives, vary from *olivine-augite-norites* (enstatite-olivine-

[1] *Rec. Geol. Surv. Ind.*, Vol. XXIII, p. 261 (1890).

[2] Another specimen obtained by Dr. King, 3 miles W. S. W. of Bétumcherú (No. 97,92) is an amygdaloidal, fine-grained variety of apparently the same rock; but is too far decomposed to permit a correct determination of its original characters.

[3] See Hacket, *Rec. Geol. Surv. Ind.*, Vol. III, p. 38 (1870).

[4] I have also found micrographic quartz in very similar augite-diorites intrusive in the unfossiliferous palæozoic slates, dolomites and quartzites of Naini Tal and in Garhwal (Nos. 9,737, 850, 854, 866).

gabbros) sometimes approaching saxonite (harzburgite) in composition, to ***augite-diorites*** (gabbros) with ***micrographic quartz***.

81. *Hemicrystalline representatives* of these rocks occur in narrow veins and as selvages to larger masses. Two of these are exceptional types related to the magma-basalts and augitites. In one case olivine is the only phenocryst in a black cryptocrystalline matrix. In the other the only phenocryst is enstatite which lies in a microlithic matrix of augite and probably felspar with residual glass. The enstatites are enclosed in a thin shell of augite, which is frequently in crystallographic continuity with isolated fragments of augite within the enstatite.

82. In the most basic members of the series, olivine is the first constituent to crystallize, and is followed in order by enstatite, biotite and plagioclase. The plagioclase grows around its associates in crystals sufficiently large to give a distinct "lustre-mottling" to the hand specimens of the coarse-grained varieties. In the less basic types, which are wanting in olivine, the enstatite, augite, biotite and felspar are crystallized in the same order. In the least basic forms, enstatite is either absent, or present in subordinate quantities, forming nuclei for the augites, which exhibit in these types a tendency to crystallize at a later stage, being developed mostly simultaneously with the felspar even to produce in some cases a sub-ophitic structure.

83. The ***micropegmatite*** is evidently the latest constituent to consolidate. It is composed of quartz and either plagioclase or a potash-felspar, which is sometimes in the form of microcline. When the quartz is intergrown with plagioclase, the latter is generally in crystallographic continuity with large adjoining crystals. The plagioclase-felspars are brown or grey in their central portions, on account of innumerable inclusions. As the periphery of the crystal is approached the colour becomes less pronounced, and the felspar, as shown by its change in extinction-angle, less basic, until at the margins, where it is intergrown with quartz to form the micropegmatite, it and the quartz become quite "water-clear," but then they invariably contain numerous acicular inclusions of a mineral resembling actinolite. These "water-clear" micropegmatite patches fill in the angles between the large crystals of felspar and augite, and though evidently younger than either of these minerals, must be regarded as crystallized in direct succession to them as the last-formed constituent during the primary consolidation of the rock.

84. In the majority of the dykes the only signs of alteration are in the formation of green hornblende and biotite with concomitant separation of magnetite where the augite comes in contact with the micropegmatite. These changes are never shown except on the sides of the augite nearest the micropegmatite. They are precisely similar in character to the alterations induced in the augites of the Carlingford gabbro (augite-diorite) by intrusions of "granophyre" (Sollas, *Trans. Roy. Irish Acad.*, Vol. XXX (1894), p. 493). But it would be impossible to regard such excessively minute patches of micropegmatite, whose felspars are in crystallographic continuity with the ordinary plagioclase-constituents of the rock, as intrusive, and such a conclusion, in the complete absence of connection with larger acid intrusions, would be quite an unjustifiable alternative to the explanation offered above (para. 83). When the rocks show signs of hydrous decomposition, the micropegmatitic patches are always found to be the centres of action. One result of this decomposition is a secondary extension of the micropegmatite by deposition of genuine "quartz of corrosion" in the surrounding felspars.

85. As the consolidation of the rock resulted first in the formation of a strong framework of coarse augite and felspar crystals, the spaces left, and now occupied by the micropegmatite, must have been in partial communication with one another. As a glass occupies a greater space than the same substance when crystallized, the micropegmatitic portions must be less compact than the rest of the rock, and being protected by the strong framework of augite and plagioclase from the pressure brought to bear on the rock as a whole, might give rise even to the production of microscopic miarolitic cavities. As these loose-textured portions are in communication with one another, they become the channels of water-circulation and consequently appear in sections as the centres of hydrous decomposition.

86. Although, as already stated, the micropegmatite in the fresh, undecomposed rocks is regarded as primary in origin and subsequent in formation to the augite and plagioclase, the considerations stated in the previous paragraph suggest that its formation is not a simple continuation of the normal crystalline consolidation of a molten magma. Any water which may have been in the original molten material would be reserved in the "mother-liquor" after the separation of the augite and plagioclase, so that the changes which subsequently occurred in the communicating inter-crystal spaces would be of an aqueo-igneous nature. This accounts perhaps for the peculiar appearance of the "water-clear" patches of micropegmatite with their acicular actinolitic inclusions, recalling at once the similar quartz which is generally regarded as secondary in decomposed rocks, and explains also the alteration of the augite where it comes in contact with the micropegmatite.

87. In describing the "granophyric gabbro" of Barnavave, Carlingford, Professor Sollas (*Op. cit.*, pp. 487—490) traced micropegmatitic patches in an augite-diorite to thin veins of "granophyre," which he regarded as intrusions of material in a state of great fluidity, and suggests that this explanation may apply also to the similar well-known cases of Carrock Fell and Penmaenmawr which are found to be in association with large masses of "granophyre." For want of evidence, however, as to the occurrence of "granophyres" in association with the Whin Sill, Professor Sollas admits that this explanation cannot be applied to the similar occurrence of micropegmatite in that rock. Neither can it be applied to the Madras dykes, which are not, so far as I know, crossed by any later intrusion of acid material. The explanation which I have offered in connection with the Madras rocks appears to account for the primary formation of micropegmatite in these rocks, as well as its secondary extension.

88. Accepting Professor Sollas' precedent for extending an explanation beyond the limits of the material under description, I would suggest the application of the explanation now offered for the Madras dykes to such cases as the Whin Sill, Carrock Fell gabbro and the Penmaenmawr enstatite-diorite; and further to suggest that even distinct veins of granophyre instead of being considered normal igneous intrusions, can best be explained as "contemporaneous veins" formed as the final stage in the consolidation of the magma from which the augite-diorite was obtained during the earlier stages of its consolidation. When the consolidation takes place under limited pressure, as was probably the case with these Madras dykes, the framework of augite and plagioclase will be sufficiently strong to prevent collapse, and the micropegmatite can thus

consolidate in the intercrystal cavites. But where the pressure is in excess of that which the framework of augite and plagioclase is able to withstand, as is more likely to be the case in large masses, the mother-liquor will be squeezed out and will consolidate as a separate mass of granophyre. Some such explanation as this I would offer to account for the frequent association of masses of augite-diorite (gabbro) with granophyre; or in other words, to account for the separation of these genetically related rocks when the magma is sufficient to form large bosses, and for their intimate microscopic association where the magma consolidates in narrow dykes.

89. Like the pyroxene-granulite series in which these basic rocks occur so frequently as dykes, they are remarkably fresh. Even the olivines show practically no signs of decomposition in the dyke-rocks and have suffered only slightly in the lava-flows, whilst signs of dynamic metamorphism are absolutely wanting. These facts are in complete agreement with the known stratigraphical history of Peninsular India which has been so remarkably free from crust disturbances since Palæozoic times.

90. As the effects of subaërial weathering must be very superficial compared to the results of the action of water charged with carbonic acid under the high pressures at the bottom of an ocean, the fresh condition of the olivine and other minerals susceptible to hydrous decomposition in these rocks is in agreement with the absence of any evidence as to the deep submergence of the parts of South India where these rocks are exposed.

91. The absence of all signs of amphibolization in the augites, which are so susceptible to the effects of dynamic metamorphism, is in agreement with the undisturbed state of all rocks younger than the Cuddapahs in Peninsular India, whilst the same feature serves generally to distinguish the basic igneous rocks of post-Cuddapah age from the epidiorites and other highly altered eruptives associated as contemporaneous lava-flows with the older Dharwar Transitions.

92. Although such petrological features can never be relied on alone for purposes of stratigraphical correlation, it is worthy of remark that augite-diorites with micrographic quartz, and equally well-preserved, occur in Transition systems like the Bijawars and Gwaliors in other parts of Peninsular India, which have generally been considered older than the Cuddapahs; but which agree, however, with the lower stages of this system in many other lithological characters.

V.—EXPLANATION OF PLATES.

PLATE I.

Fig. 1.—Olivine-norite, S. of Kaithaha, near Saria on the Sone river, Ramnagar Tahsil, Rewa State. No. 10,588; slide 2125. Magnified by 20 diameters. Olivine in rounded crystals with reaction-rims of a colourless granular enstatite forming the inner zone and fibrous actinolite forming the outer zone. The colourless portion is plagioclase in which two crystals of enstatite are shown. Where the small enstatite crystal, near the upper margin of the slide, approaches olivine the only sign of a reaction-rim is a thin band of the colourless granular mineral separating the enstatite crystal from

the olivine. Such thin bands of the colourless mineral are often found in crystallographic continuity with the neighbouring primary crystal of enstatite.

Fig. 2.—Olivine-enstatite-basalt.—Dyke in "pyroxene-granulites," Coonoor, Nilgiri hills, Madras Presidency. No. 8,759; slide No. 1599. Magnified by 20 diameters. The phenocrysts in this rock are olivine, enstatite and plagioclase. There are numerous glomero-porphyritic aggregates formed of one crystal of olivine in the centre with numerous enstatite-crystals around. Such a group is shown in the centre of the field. The matrix is pilotaxitic, possibly hyalopilitic, containing augite, biotite, enstatite, felspar and magnetite. Towards the central portions of this dyke the crystals of the groundmass are more clearly-defined, and the pleochroism of the rhombic pyroxene often well exhibited. (See paras. 36—38.)

Fig. 3.—Magma-basalt without augite.—Thin vein in "pyroxene-granulite," near Poorsy, north-north-west of Wandiwash, Madras Presidency. No. 1,842; slide No. 2027. Magnified by 80 diameters. The rock has a black, almost opaque, cryptocrystalline or glassy matrix in which olivine phenocrysts only occur. The crystals are well shaped, zoned and often corroded by the magma, as shown by this specimen. The cracks running across the matrix are filled in with colourless decomposition-products.

Fig. 4.—Olivine-norite-variolite.—Selvage of vein 2 feet wide in "pyroxene-granulite," Coonoor, Nilgiri hills, Madras Presidency. No. 8,757; slide No. 2198. Magnified by 20 diameters. The varioles are brown in colour and sprinkled with magnetite-dust. Glomero-porphyritic aggregates of olivine and enstatite precisely resembling those shown in fig. 2, as well as isolated crystals of enstatite, are scattered through the cryptocrystalline matrix.

Fig. 5.—"Norite-felsite,"—Dyke 20 feet wide in "pyroxene-granulite," Eriyúr, South Arcot district, Madras Presidency. No. 9,782; slide No. 2197. Magnified by 20 diameters. Porphyritic crystals of colourless enstatite in a matrix of augite and long microlites of felspar with black interstitial matter, which may be vitreous. The way in which the long microlites of felspar are wrapped around the pyroxenes forms a perfect imitation on a very small scale of the blades of plagioclase in the coarse-grained rock from Salem described in para. 56. The large phenocrysts of enstatite are generally encased in a thin shell of augite, which is seen between crossed Nicols to be in crystallographic continuity around, and often also with apparently isolated fragments of augite within, the enstatite phenocrysts. This rock bears to the augite-norites precisely the same relation as a felsite does to a granite. It may therefore be called a "norite-felsite," or any convenient name

which indicates that its composition is that of a norite and its structure felsitic.

Fig. 6.—Augite-diorite with micropegmatite.—Dyke in "pyroxene-granulite," Mailam, South Arcot district, Madras Presidency. No. 9,795; slide No. 2133. Magnified by 12 diameters. Crossed Nicols. The rock is composed of augite, plagioclase and a micropegmatitic intergrowth of quartz and felspar playing the rôle of groundmass and regarded as primary in origin.

PLATE II.

Fig. 1.—Basal section of olivine crystal, showing the traces of brachypinacoidal cleavage planes crossing the cut edges of the dendritic inclusions at right angles. The quartz wedge shows the latter to lie in the direction of the axis of maximum optical elasticity $\mathfrak{a}$, whilst the cleavage cracks are parallel to the axis of minimum optical elasticity $\mathfrak{c}$ (See para 13). From *Olivine-augite-norite,* near Saria Rewa. Rock No. 10,588; slide No. 2125. Magnified by 180 diameters.

Fig. 2.—Intergrowth of pyroxene-crystals, showing the peculiar microperthite-like structure in one of the individuals (P). The positions of extinction in the individuals P, P_I, P_{II}, and P_{III} respectively are shown by the arrows. From the same *Olivine-augite-norite*; slide No. 1895. Magnified by $\frac{40}{3}$ diameters. (See para. 18.)

Fig. 3.—Reaction-rim between olivine and plagioclase. *O*=Olivine, *P*= Plagioclase, *E* = Enstatite with its secondary enlargements, *e*, which are in crystallographic continuity with the original crystal *E*, and in one place form part of the reaction-rim with the green actinolite, *a*. It will be noticed that the actinolite, *a*, appears only between the secondary enstatite, *e*, and the plagioclase, not between the latter mineral and the primary enstatite, *E*. *E*. shows feebly the pleochroism of hypersthene, whilst *e* is perfectly colourless. Slide No. 2125. Magnified by $\frac{48}{3}$ diameters. (See para. 14.)

Fig. 4.—Augite-andesite, forming the marginal portion of a large mass of augite-diorite with micropegmatite at Perumbakam, South Arcot district, Madras Presidency. It consists of a hyalopilitic groundmass of augite, plagioclase, biotite, magnetite and glass with phenocrysts of augite (A) and plagioclase felspar (F) showing in the glomero-porphyritic groups approximately simultaneous crystallization of the two minerals. Rock No. 9,788; slide No. 2130. Magnified by $\frac{20}{3}$ diameters. (See para. 75.)

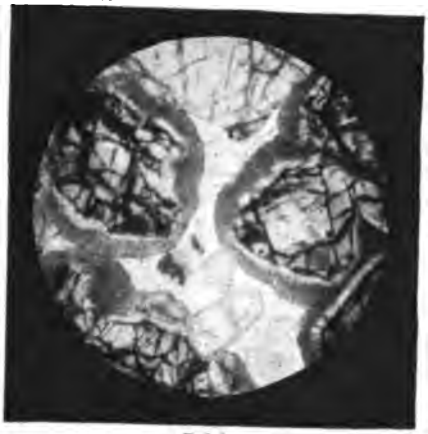


Fig. 1.

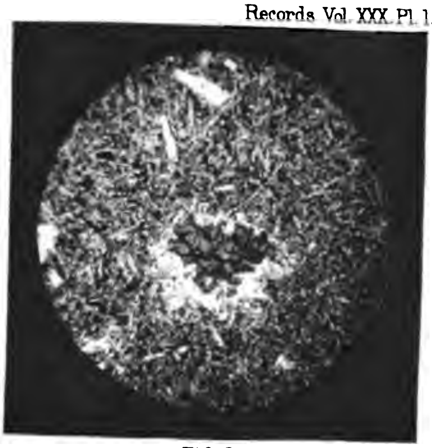


Fig. 2.

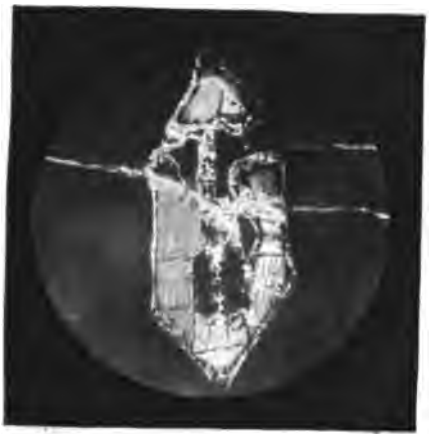


Fig 3.

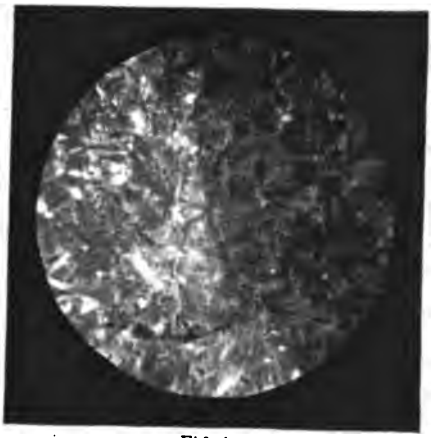


Fig 4.

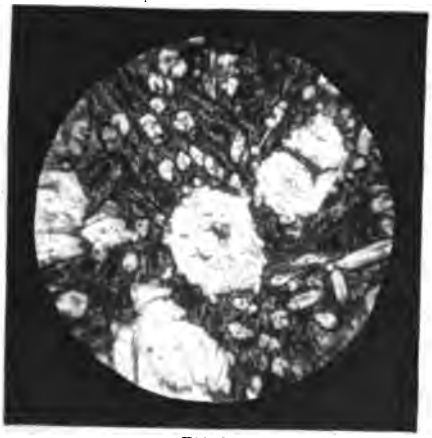


Fig. 5.

Fig. 6.

Photo-etching.

Survey of India Offices, Calcutta, January 1897.

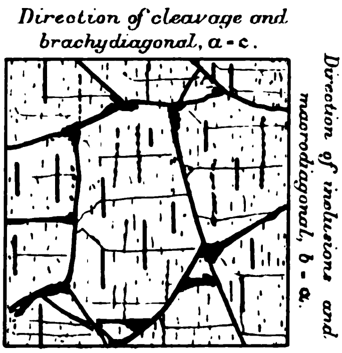


Fig 1.

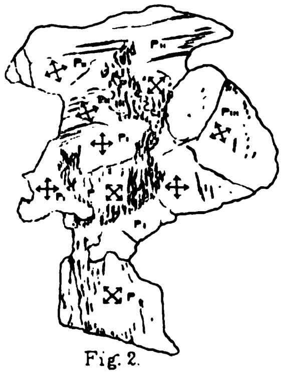


Fig. 2.

Fig. 3.

Fig. 4

BASIC DYKES OF PENINSULAR INDIA.

The reference of the genus Vertebraria *by* M. R. ZEILLER; *translated by* E. VREDENBURG, A. R. C. S., *Assistant Superintendent, Geological Survey of India.*[1]

Few fossil genera have so much perplexed the minds of most eminent palæobotanists for the last 50 years as the genus *Vertebraria*, without any definite conclusion having been arrived at respecting its true affinities. This genus was established by Royle in 1839 to include flattened axes of varying width, usually with a more or less distinct median groove, giving off at right angles transverse furrows more or less irregularly spaced, sometimes alternate, sometimes opposite, and dividing either side of the impression into a series of successive joints. Moreover, the widest specimens usually exhibit upon each side other longitudinal grooves parallel with the central one, only not so distinct. These grooves, longitudinal as well as transverse, may be replaced by projecting ridges, according to the mode of preservation of the fossil. The axes are either simple or provided with branches, alternately disposed on either side, but irregularly spaced.

A few specimens lying at right angles to the planes of bedding, show upon their cross section a series of wedge-shaped segments radiating from a common centre and more or less closely packed; this led some authors to arrive at a conclusion, which was subsequently recognised as unfounded, that they were *Sphenophyll-oideæ* with very numerous leaf-whorls, close set along the stem. Bunbury regarded the specimens he studied as roots. O. Feistmantel who has had the opportunity of examining a large number of specimens obtained from India and Australia, concluded, but without committing himself any further, that *Vertebraria* is the root or rhizome of some other plant, and probably of an Equisetaceous plant such as *Schizoneura* or *Phyllotheca*; but this view seems difficult to accept as the transverse folds of *Vertebraria* often intersect only half the structure, and the existence of real articulations like those of the *Equisetaceæ* appeared far from evident.

Up till now, *Vertebraria* had been met with only in India in the lower Gondwana series, and in Australia in the Newcastle beds. I have recently been able to detect its occurrence in another region, the permo-triassic deposits of the Transvaal belonging to the Beaufort stage; it is fairly abundant amongst the specimens collected by M. de Launay, mining Engineer, in the neighbourhood of Johannesburg. It is associated, as in Australia and India, with numerous impressions of *Glossopteris*, and as very few other vegetable remains are met with, I was led to consider whether this association of *Glossopteris* and *Vertebraria* did not indicate some mutual relationship.

By splitting up these Transvaal specimens and carefully developing the impressions which they contained, I was soon able to ascertain the presence, upon several specimens of *Vertebraria*, of more or less abundantly ramified roots starting from some of the transverse grooves, from which I was able to infer that they are undoubtedly rhizomes. Further, a study of the structures exhibited by the impressions has enabled me to conclude that these rhizomes consisted of a central axis provided with a variable number of longitudinal wings anastomosing two by

[1] *Comptes Rendus*, cxxii, 744. I am indebted to Surgeon-Major D. Prain, Curator of the Herbarium, Royal Botanical Gardens, Sibpur, for kindly revising the translation. —R. D. O.

two from place to place; the characteristic transverse grooves observed upon the surface corresponding to these anastomoses.[1]

Now such a disposition is actually met with in certain ferns, particularly in *Struthiopteris germanica* whose rhizome is provided with a variable number of columns (*stèles*) each situated towards the extremity of a projecting wing, and successively uniting two by two to give rise to the leaf-bundles. If the leaves of such a rhizome were fewer and not so regularly spaced it would produce an impression resembling that of *Vertebraria*. The irregularities shown in the interspacing of the transverse furrows could not, however, invalidate the reference of this fossil genus to the ferns, some of which, particularly *Oleandra*, exhibit at the present day, still greater irregularities with regard to the distribution of their leaves, which may be more or less apart, or else closely packed in pseudo-verticils.

It appeared probable to me, therefore, that *Vertebraria* belonged to *Glossopteris*, but this was only a conjecture requiring further verification if possible. By means of a minute examination of the impressions collected by M. de Launay, I have been fortunate enough to verify this point. First I was able to follow up to its base a *Glossopteris* leaf fixed to a *Vertebraria*, and to observe that its midrib bent round so as to fit exactly into a transverse furrow of this rhizome where it terminated; their mutual relation was, however, not altogether beyond doubt, and therefore, although such a coincidence would seem most unlikely, it might still have been objected that this was merely an accidental juxtaposition. At last, on a specimen exhibiting a more distinct transverse folding, which assumed the appearance of a leaf scar, I was able to discover a group of bundles starting from this anastomosis of longitudinal ridges and, following it outwards, to discern its continuation into the midrib of a *Glossopteris* leaf, imperfectly preserved, but perfectly recognisable.

Vertebraria is therefore nothing but the rhizome of *Glossopteris*, and this observation at once solves the problem of its interpretation and adds greatly to our knowledge of this genus of Ferns which has played so important a part in the flora of one of the two great botanical provinces of the close of the palæozoic era. Somewhat similar in habit to *Oleandra*, that is with leaves now wide apart, now clustered in tufts, *Glossopteris* had winged rhizomes very analogous to those of *Struthiopteris germanica*. As in the last mentioned plant these rhizomes in all probability gave off stolons provided first with leaf-scales and producing only after a time normally developed leaves. I have indeed noticed amongst the Johannesburg impressions, numerous scales, triangular or oval in outline, the limb of which appears to have been rather thick and coriaceous, whose anastomosing venation is sometimes remarkably similar to that of *Glossopteris*; one of them, more completely developed, comes so near, both in shape and dimension, to certain leaves of *Glossopteris browniana*, that its reference to this species seems to leave no room for any doubt. Contrary to what takes place in *Struthiopteris germanica*, where the two kinds of leaves, underground scales and aërial fronds, remain absolutely distinct, it would appear that in *Glossopteris*, whose stolons were perhaps epigæous, there was a gradual passage from scales to normal leaves.

[1] In the original: "ces rhizômes etaient fórmées d'un axe central muni d' un nombre variable d'ailes longitudinales s'anastomosant deux à deux de distance en distance, les cannelures transversales caractéristiques q'on observe à leur surface correspondent précisément à ces anastomoses." As will be seen from the succeeding paper the structure of the Indian specimens is not in accord with this description.

On a Plant of Glossopteris with part of the rhizome attached, *and on the* structure of Vertebraria, *by* R. D. OLDHAM, *Officiating Director, Geological Survey of India* (with Plates III to V).

The interest of the foregoing paper, as not only extending the range of the characteristically Indian genus *Vertebraria*, but also settling its true botanical nature, so long in doubt, has seemed sufficient to justify the publication of a translation in the Records of the Geological Survey. Besides its purely botanical and geological importance it is of interest in adding yet another to the long list of instances of independent and simultaneous discovery. During the last working season I was fortunate enough to find, in the lower Gondwanas of south east Rewah, a bed crowded with the remains of *Glossopteris*, *Macrotæniopteris*, *Schizoneura*, etc., and among them a specimen, figured on Pl. III, of a clump of *Glossopteris communis* fronds, evidently springing from a fragment of the rhizome. The specimen was sufficiently striking to attract the notice of the labourers I had employed to dig out the bed, but unfortunately the most careful search failed in discovering either the reverse impression or the continuation of the rhizome; the one specimen figured is consequently all the material available. The state of preservation of the specimen is not all that might be desired, but it is sufficient to enable the generic and specific position of the plant to be determined without doubt; the peculiar manner of association of the group of fronds is incompatible with any supposition other than that they originally formed part of the same plant, and it would be unreasonable to suppose that the position of the fragment of rhizome at their joint bases is merely accidental; we may take it therefore that we have preserved a whole plant of *Glossopteris* with a portion of its root-stock. This is of itself interesting as showing the habit of growth of the plant, but besides this the small rhizome shows indistinctly, it is true, but recognisably, the median ridge and transverse partitions of *Vertebraria*. Taken in conjunction with Mr. Zeiller's observations this specimen may, therefore, be regarded as establishing the true nature of *Vertebraria* as the rhizome of a fern and not, as is more often supposed, of an equisetaceous plant.[1]

The discovery of the botanical position of the *Vertebraria* naturally revives the interest in its structure, and as this is but imperfectly treated in any of the descriptions I have come across, I have made a re-examination of the material in the Museum of the Geological Survey and offer the following description of the facts disclosed without any expression of opinion as to their botanical application.

In its most common and typical form *Vertebraria* is preserved as an impression on the surface of bedding of shale or sandstone. This long, and generally narrow,

[1] It may be of interest to note that this is not the first specimen of a clump of *Glossopteris* fronds which has been found in India. This specimen figured by Dr. Feistmantel, under the name *Sagenopteris* (?) *longifolea* (Pal. Indica, ser. xii, III, pl. XLA, fig. 1) is in a very poor state of preservation, but can be recognised as a group of fronds of *Glossopteris* type, resembling *G. communis*. One side only of the stalk is preserved, but that shows distinct signs of a transverse articulation. The specimen is evidently of a similar nature to that found in S. Rewah, and resembles this so much that, with all deference to Dr. Feistmantel's authority, I feel constrained to regard it as properly belonging to the genus *Glossopteris*, and not to *Sagenopteris*, to which he doubtfully assigned it.

impression is typically divided down the centre by a ridge or a furrow, and on either side divided by transverse prominences and grooves, generally arranged alternately in either half, and in the most perfectly preserved there is usually an elevation and furrow close together and then an interval between them and the next pair Occasionally the divisions on either side of the median axis are opposite each other, but as a rule they are not so, and the occasional continuation of one of the transverse divisions on the other side of the central axis is evidently accidental. In another shape, described as *V. radiata* by Royle,[1] it appears on the face of the bedding plane as a series of triangular impressions arranged round a central axis; in section across the bedding plane, it is seen to be composed of number of close set layers, and it was this form which led McCoy to class *Vertebraria* with the *Marsielaceæ*[2] and Unger[3] and de Zigno[4] to describe it as a *Sphenophyllum*, all three authors looking on the fossil as the remains of a central stem with close set whorls of leaves.

This description is irreconcilable with the fact that the two forms are clearly a different mode of preservation of one and the same thing, and moreover a close examination of specimens of *V. radiata* show the occasional preservation of an outer shell of coaly matter and of a similar substance occupying the intervals between what would be the edges of the leaves and connecting one with the other in a vertical direction. It is clear in fact that *V. radiata* was a stem with a central axis, connected with the outer shell by radiating longitudinal septa, which again were connected by close set transverse septa in each segment. The ordinary form of *V. indica* would be the impression of a similar stem in which the septa were at longer intervals apart, and which in consequence of the smaller resistance to crushing resulting from this, has only been preserved as a flattened impression.

It would be quite possible to explain the peculiar markings in the manner in which M. Zeiller has done, and this hypothesis would fit in with the occasional occurrence of two or even three longitudinal divisions and of three or four bands of transverse ridges and depressions. Fortunately, however, there are in our collection some specimens of *Vertebraria* from the Aurunga field, preserved in a different manner, which throw great light on the structure of *Vertebraria*. In these the vegetable matter has been converted into a dark brown ferruginous substance, round which the matrix is indurated with a ferruginous cement. The rest of the matrix, whether sandstone or shale, is soft and in many cases easily cleared away from the fossil. The *Vertebraria* shows up either as a transverse section on the face of the rock, or when the axis runs along the exposed surface, as projections, differing in appearance from the more usual form, but easily recognisable as the same thing preserved in a somewhat different manner. The first of these to be noticed is that represented in pl. IV, figs. 2-5, which I have succeeded in developing from a piece of sandstone, on which only the ends and part of one side of the fragment were originally visible.

Here the end view fig. 2, shows a central axis and a series of radiating wings,

[1] Illustrations of the Botany and other Branches of the Natural History of the Himalaya Mountains, Plate II, fig. 5, 6, 7.

[2] *Ann. Mag. Nat. Hist.* XX, 145 (1847).

[3] Genera et species Plantarum Fossilium, 1850, p. 71.

[4] Flora Fossilis Formations oolithicæ, 1856, p. 52, where Ettingshausen is quoted as taking the same view.

which are not connected at their outer extremities. It must not, however, be concluded from this, that the stem was of a stellate section, for in specimens of the ordinary sort the remains of an outer coating of carbonaceous matter can sometimes be found, though it was evidently thin and perishable. Even in the specimen under consideration there are traces of an expansion at the end of the rays which must represent a part of the original rind; and in other specimens of the same nature, and from the same locality, this is partly preserved as shown in pl. V, fig. 4. It will be noticed that the longitudinal septa do not all radiate from the central axis, but that in one case the septum bifurcates and gives rise to two septa; moreover, a comparison of figs. 2 and 3 shows that the point of bifurcation of the septum is further removed from the axis at one end of the specimen than at the other.

The transverse septa are well seen on the sides of the specimen; in fig. 3 the broad triangular patch is one of the septa exposed on the broken end of the specimen and on the others, the manner in which each longitudinal section is independently divided by transverse septa is very clearly shown.

The two next specimens to be described have both been figured before,[1] but are reproduced here, one for convenience, the other because the specimen has been developed so as to show more than was originally to be seen. In pl. V, fig. 3, we have three longitudinal ridges, united at irregular interval by transverse bars, which there is no difficulty in recognising as a variant of the typical form in which *Vertebraria* is preserved. In fig. 2 we have four ridges and three sets of transverse bars. In the specimen, more clearly than in the figure, it is possible to make out that the longitudinal and transverse ridges represent the ends of corresponding septa, while in the section made by obliquely truncating the end of the impression, the septa, corresponding at their terminations to one of the longitudinal ridges, can be seen radiating from a central axis.

In the next specimen to be described the mode of preservation is somewhat different; instead of being converted into iron oxide the vegetable matter has disappeared leaving a cavity in its place. The specimen (pl. V, fig. 1) shows a longitudinal section, the rock having broken through the cavity left by two opposite radial septa, and from the surface of the mould a series of clefts penetrate vertically downwards and represent the transverse septa. Another longitudinal septum is represented by a cleft penetrating obliquely into the rock, and the transverse clefts running down from it can be seen in close proximity to, but not as a rule coincident with, those above.

From these specimens to the more usual form of preservation is a short step, and we can recognise the latter as the impression of the flattened stem, the longitudinal divisions representing the impression either of the central axis or the ends of radial septa, and the transverse ones the impression of the transverse septa, which sometimes occur opposite each other, but more commonly are not coincident. Sometimes, instead of being merely the impression of a crushed stem, the hollow spaces between the septa have become filled with sand, and the *Vertebraria* appears as a series of separate joints, between which thin partings of coaly matter are seen.

In the rarer forms of preservation described above there is seldom any trace of an outer sheath connecting the ends of the radial septa, but in the more usual

[1] Pal. Indica, series xii, IV, Pl. IVa, fig. 5, 9.

mode of preservation there is not uncommonly an outer film of coaly matter, and in two specimens figured by Dr. Feistmantel[1]—the outer sheath is conspicuously preserved, and can be seen to have been smooth, with a longitudinal striation; moreover, the flattening undergone by the stem in the ordinary mode of preservation shows that the matrix could not obtain a ready access to the intervals between the septa. It would seem, however, that the outer rind must have been much less substantial and more perishable than the central core or the septa.

Summing up the evidence we find that *Vertebraria* consisted of a central axis, more or less well marked, joined to an outer rind by a series of radial septa, which are usually eight in number in those specimens preserved so as to show a transverse section, and having the spaces between the radial septa divided into chambers by transverse partitions. The transverse partitions on either side of each radial septum are in no case coincident with each other, and there is an appearance of their being arranged spirally round the central axis, but the material available is insufficient for the establishment of this point. From the readiness with which the interspaces between the septa become filled by the matrix and the completeness of their obliteration where this is not the case, it is probable that they were air chambers and not filled with any form of celular tissue, however soft and perishable.[2]

Branching of these stems takes place in two distinct ways. Either as in pl. IV, fig. 1, the central axis itself breaks up into two or more branches, or branches are given off from the side of the stem. There are numerous specimens showing this latter and more common form of ramification, several of which have been figured by Dr. Feistmantel. It is not always possible to make out clearly the exact point at which the stem and branch join, but in all those which I have examined the junction seems to take place exactly on one of the transverse septa and, as far as can be made out, at its junction with a longitudinal septum. In some cases the junction seems not to coincide with any transverse septum, but in these cases the appearance may be deceptive and has, besides, only been observed in thin branches or rootlets, which do not exhibit the typical *Vertebraria* structure and may be functionally different. On the whole, however, the statement above seems to represent the facts, but certainty will only be attainable after the careful development of specimens well preserved in the round.

P. S.—The foregoing description had been written and set up in type for publication in part 4 of the Vol. XXIX of these Records, but had to stand over to the present number owing to a delay in the preparation of the plates. Meanwhile we have received, through the courtesy of M. Zeiller, a copy of a more detailed description[3] published by the Geological Society of France with full illustrations of the specimens studied by him. The description and diagrams leave no doubt of his interpretation of the structure of *Vertebraria*, and it is evident that the in-

[1] Pal. Indica, series xii. III, Pl. XIIA, 10, XIVA, 2.

[2] It will be noticed that this description agrees with that of Bunbury (Q. J. G. S., XVII, 1861, p. 330), except that he does not appear to have recognised the continuous radial septa, no specimens showing a transverse section having been included in the collection examined by him. Solms Laubach in his Fossil Botany (English translation, p. 366) has adopted a description agreeing in all respects with that in the text above.

[3] Etude sur quelques plantes fossiles, en particulier *Vertebraria* et *Glossopteris*, des environs de Johannesburg (Transvaal); *Bull. Soc. Géol. de France*, 3rd series, XXIV, 349–378 (1896).

completeness of the material at his disposal has led him to overlook the outer sheath connecting the extremities of the radial septa. The analogies he sees between *Vertebraria* and the rhizome of *Sturthiopteris germanica* are consequently unfounded, but the main fact, the connection between *Vertebraria* and *Glossopteris*, remains unaffected.

M. Zeiller in the same paper notices[1] that Dr. Feistmantel's figure of *Sagenopteris longifolia* referred to above, seems to represent a group of fronds at the end of a rhizome, rather than a palmate leaf. He also remarks that Dr. Feistmantel's *Sagenopteris polyphylla* (Pal. Indica, ser. xii, III, pl. XLI A, fig. 4) appears to be the same specimen as that figured by McClelland under the name *Glossopteris acaulis*. I can confirm this suggestion, as after a careful examination of the figures, the specimen, and the registers of the Survey I had already satisfied myself that the specimen described was the same in both cases. This specimen and that forming fig. 3 of the same plate belong to the same species, each represents a group of fronds which individually resemble *Gl. conspicua*, Feist., in shape and venation. The small fragment of stem or stalk preserved in the specimen fig. 3 is only ·25 inch long and ·1 inch across; it is covered with a layer of carbonaceous material, the outer surface of which shows a longitudinal striation, but no trace of the characteristic *Vertebraria* structure.

I have allowed the specific name *Gl. communis*, Fstm., to stand—although M. Zeiller in the paper under notice has shown that the characters which distinguish *V. indica*, Schimper and *V. communis*, Fstm., may be found in the same frond—as it seems very doubtful how far the distinctions between the species of *Glossopteris* represent true specific differences in the plants as they lived, and it seems convenient to retain the names as descriptive of different types of venation of the fronds.

EXPLANATION OF PLATES.

PLATE I.

A plant of *Glossopteris indica*, Feist., with portion of root-stock attached; two-thirds natural size. The root-stock separated, twice natural size; from Reohal S. Rewah, Lat. 23°52′ Long. 82°22′.

PLATE II.

Fig. 1. *Vertebraria indica* showing ramification by splitting up of the main axis. This specimen shows the usual mode of preservation and appearance of *Vertebraria*, as well as the most common type of ramification; Bajbai, S. Rewah, Lat. 24°4′ Long. 81°56′.

Figs. 2-5. Different views of a fragment of *Vertebraria*, showing radial and transverse septa; from the Aurunga coalfield, Sukri river.

[1] Loc. cit., p. 371.

PLATE III.

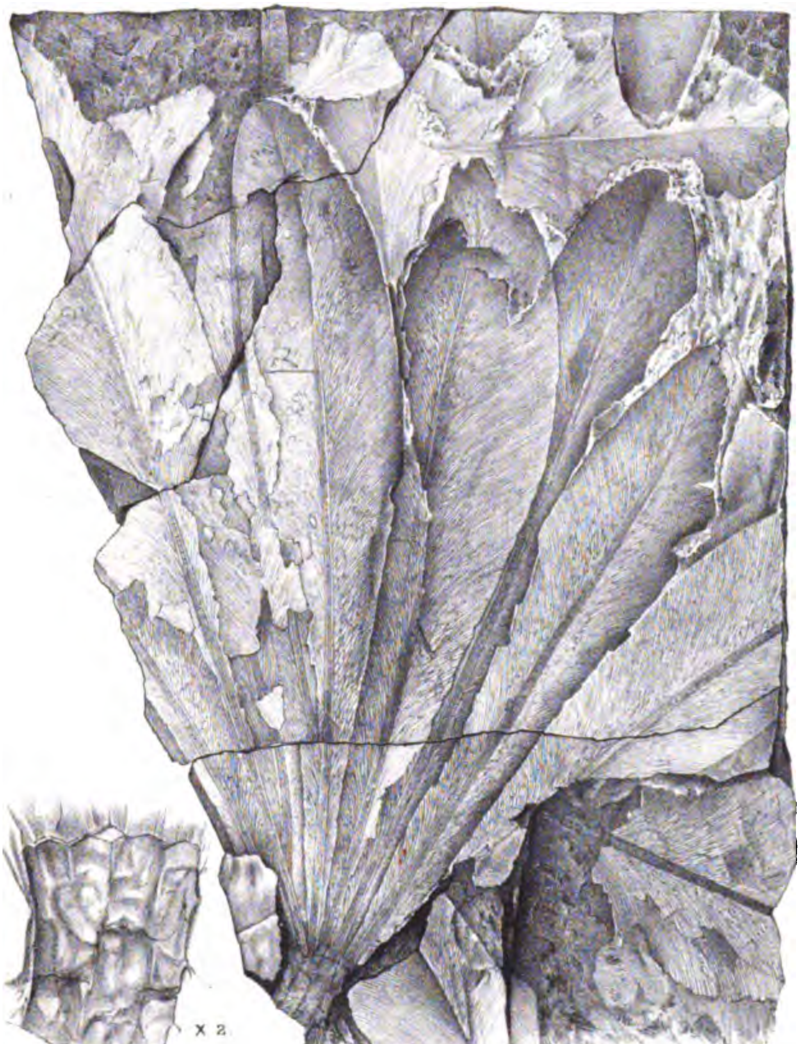
Fig. 1. Cast of *Vertebraria*, with the longitudinal and transverse septa represented by cavities; Aurunga coalfield, Sukri river.

Fig. 2. A specimen showing the longitudinal and transverse septa standing out in relief by the weathering away of the softer matrix; figured in Pal. Indica, ser. xii, IV, pt. ii, Pl. IV A, fig. 5, same locality as fig. 1.

Fig. 3. Another, smaller specimen showing the same features as fig. 2; figured in Pal. Indica, ser. xii, IV, pt. ii, pl. IV A, fig. 9; same locality as figs. 1 and 2.

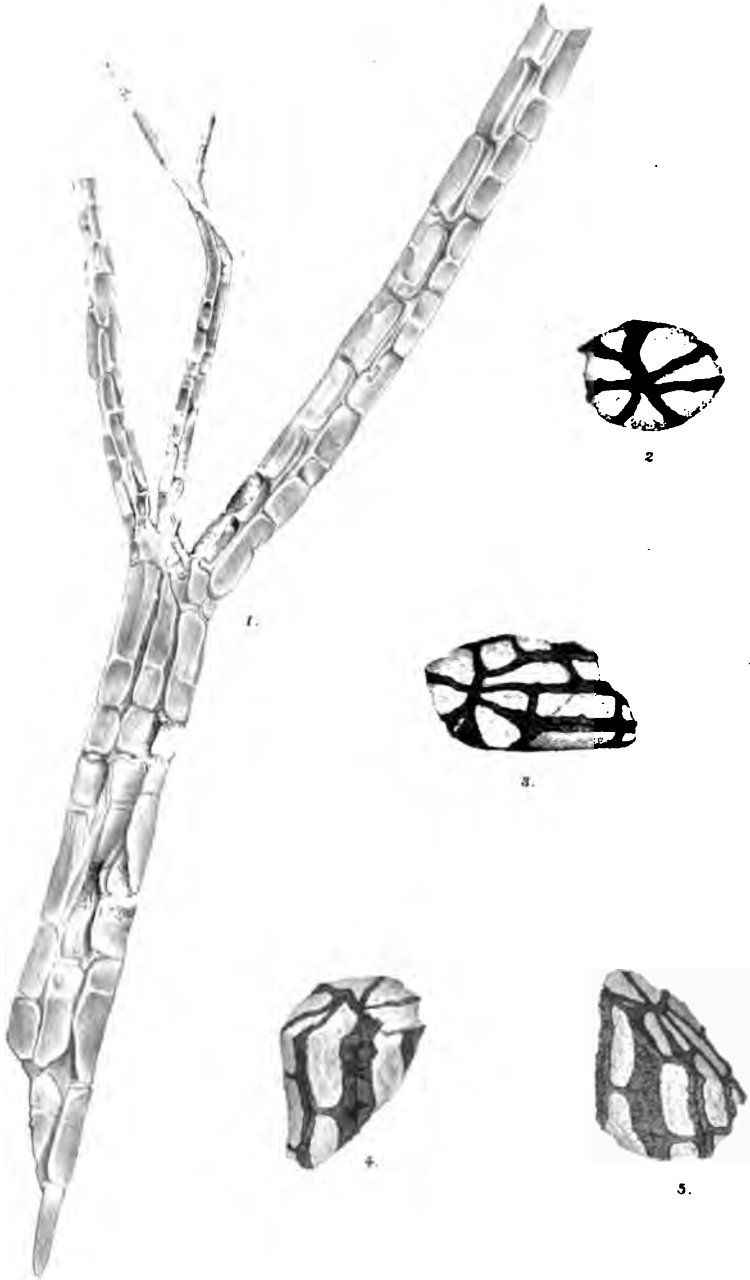
Fig. 4. A fragment preserved in the same manner as pl. II, figs 2-5, but showing part of the outside rind connecting the ends of the radial septa: same locality as Pl. II, figs. 2-5.

R.D. Oldham.



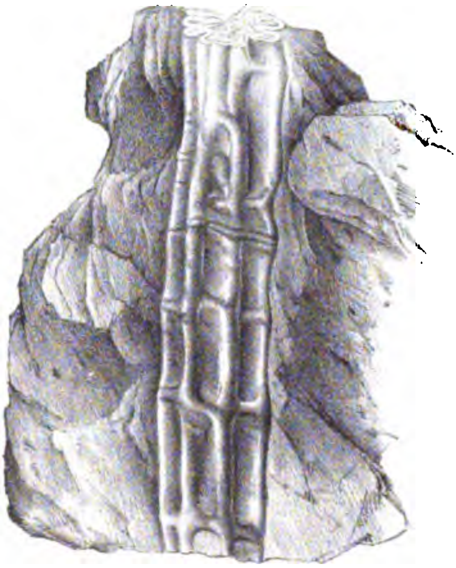
GLOSSOPTERIS COMMUNIS. $\times\frac{2}{3}$

R. D. Oldham. Records, Vol: XXX. Pl. IV.



VERTEBRARIA INDICA.

R.D. Oldham



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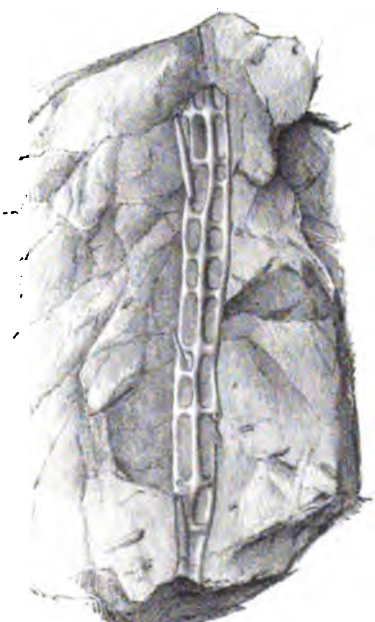

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VERTEBRARIA INDICA.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.	1897.	May.

The Cretaceous Deposits *of* Pondicherri, *by* DR. FRANZ KOSSMAT.

Translated by ARTHUR H. FOORD, F.G.S., *and* MRS. A. H. FOORD.

ERRATA IN VOL. XXX, Pt. I.

p. 46,	line 11,	for	*Marsielaceæ*	read	*Marsileaceæ*.
„ 49,	„ 3,	„	*Sturthiopteris*	„	*Struthiopteris*.
„ 49,	„ 27,	„	Plate I	„	Plate III.
„ 49,	„ 28,	„	*indica*	„	*communis*.
„ 49,	„ 31,	„	Plate II	„	Plate IV.
„ 50,	„ 1,	„	Plate III	„	Plate V.

The frequent occurrence of gastropod and bivalve types of a later period was explained by Forbes on the supposition that the Indo-Pacific area was their original habitat, from which they afterwards penetrated into the European seas.

A. d'Orbigny [2] who, almost at the same time as Forbes, had studied a smaller collection of Pondicherri fossils, came to quite a different conclusion. He considered them to be of upper cretaceous age and in his "Prodrôme de Paléontologie" [3] placed the whole of the fauna (also the species described by Forbes) in his étage senonien, an opinion which is proved at present to be the

[1] *E. Forbes:* Report on the Fossil Invertebrata from Southern India collected by Mr. Kaye and Mr. Cunliffe. Trans. Geol. Soc., London, 2nd ser., VII, 1846, pp. 97—174, pl. VII—XIX.

[2] Voyage de l'Astrolabe et de la Zélée. I. Paléontologie, Atlas, pl. I—V.

[3] Paris, 1850. Vol. II, p. 211 ff.

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PART I. ON THE STRATIGRAPHY AND FAUNISTIC RELATIONS OF THE CRETACEOUS OF PONDICHERRI.

The cretaceous rocks of Pondicherri, long known in geological literature, had shown numerous peculiarities in their fauna, which were with such difficulty brought into harmony with the then imperfect knowledge of the European cretaceous faunas, that the three distinguished palæontologists, Edw. Forbes, A. d'Orbigny, and F. Stoliczka, who undertook their study came to entirely different conclusions.

Forbes,[1] who had the opportunity of working up the largest collection of Pondicherri fossils made at any time, concluded that in spite of the great number of tertiary and recent molluscan genera, he was dealing with a cretaceous deposit corresponding with the European neocomian. What led him to this conclusion was the occurrence of a great number of ammonites, whose nearest relations he found in the European neocomian; he even went so far as to identify some specimens with species of the lower cretaceous (*Am. juilleti*, Orb., *Am. rouyanus*, Orb.). Besides this the occurrence of numerous *Hamites*, which at that time were only little known in the upper cretaceous, gave an older facies to the cephalopod fauna. The frequent occurrence of gastropod and bivalve types of a later period was explained by Forbes on the supposition that the Indo-Pacific area was their original habitat, from which they afterwards penetrated into the European seas.

A. d'Orbigny [2] who, almost at the same time as Forbes, had studied a smaller collection of Pondicherri fossils, came to quite a different conclusion. He considered them to be of upper cretaceous age and in his "Prodrôme de Paléontologie" [3] placed the whole of the fauna (also the species described by Forbes) in his étage senonien, an opinion which is proved at present to be the

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[2] Voyage de l'Astrolabe et de la Zélée. I. Paléontologie, Atlas, pl. I—V.

[3] Paris, 1850. Vol. II, p. 211 ff.

correct one. This result is to be traced to the circumstance, that d'Orbigny, from his own observation, knew the fauna of the French upper senonian, which gives the most important basis for the determining of the age of the Indian specimens. Since no correct stratigraphical account was then at their disposal, Forbes as well as d'Orbigny treated the Pondicherri deposits as a whole. Such an account was first given by H. F. Blanford [1] as a result of the geological survey of the district, and the division made by him formed the basis of Dr. Stoliczka's [2] studies on the Pondicherri fossils. Blanford distinguished two fossil-bearing divisions (1) the "Valudayoor group," which had given by far the greatest number of species described by Forbes, and was thought to be neocomian, and (2) a later division, which in its facies and fauna represented an undoubted equivalent of the Ariyalúr stage of the Trichinopoli district. This latter determination was completely confirmed by F. Stoliczka; but as to the Valudayur stage he thought that he recognised in its ammonite fauna resemblances to the Utatúr stage (cenomanian) of the Trichinopoli district,[3] and consequently placed it, in this horizon.

It must have appeared remarkable that the fauna of the lower division of Pondicherri was not so different from that of the typical Ariyalúr stage as it might have been supposed to be, considering the great accepted difference of age between them, but that a great many species were common to the two groups, as Blanford had already put in evidence. This was the case with the cephalopoda, but it was still more striking with the gastropods and bivalves. A series of species which originated in the characteristic bluish shell-sandstone of the Valudayur beds proved to be undoubtedly identical with known Ariyalúr forms, and Stoliczka came gradually to the conclusion "that the extent of the Valudayoor group as being the lowest and about equivalent to the Ootatoor beds must be accepted very cautiously. The larger number from these Pondicherry beds are rather identical with those from the Arrialoor group."[4] Stoliczka could not come to a complete solution of the question as long as he was compelled to believe in the identity of a larger number of Valudayur and Utatúr ammonites, and thus the Valudayur beds remained a special division belonging to the cenomanian, appearing as such in the "Manual of the Geology of India, 2nd Edition" (Calcutta, 1893, p. 235), and all other isolated deposits standing in near relationship to the Valudayur stage were accordingly assigned to the cenomanian. Some years ago when I began the examination of the fossils collected by Dr. H. Warth in the Trichinopoli district, I was likewise occupied with the question of the age of the Pondicherri beds, and I undertook a journey to London for the special purpose of examining Forbes' original specimens preserved in the collections of the Geological Society. It was soon seen that the formerly accepted conformity of the Valudayur and Utatúr ammonites did not exist, and that the ground upon which the identification of the two deposits rested was removed, an opinion which

[1] H. F. Blanford: On the Cretaceous and other Rocks of the South Arcot and Trichinopoly districts, Madras; Mem. Geol. Surv. Ind., IV, 1862, p. 156 ff.

[2] F. Stoliczka: Cretaceous Fauna of Southern India (4 Vols.) Palæontologia Indica. Calcutta, 1865—1873.

[3] F. Stoliczka: Cretaceous Fauna of Southern India, Vol. I. (*cf.* the list, pp. i.—ix.)

[4] F. Stoliczka: *ibid*, Vol. II, p. 217.

I published, after my return from London, in a paper upon the zoogeographical character of the cretaceous of Southern India.[1]

In the winter of 1894-95, Dr. H. Warth[2] was deputed to reexamine the Pondicherri district, in which his principal task was the collection of fossils for the exact stratigraphical division of the cretaceous deposits. This undertaking was accomplished by Dr. H. Warth in an efficient manner, and he succeeded, in spite of the lack of good exposures and in spite of the exhaustion of the locality, formerly so rich in fossils, in amassing a collection which permitted a correct idea of the succession of the fossil-bearing horizons being attained.

These fossils were transmitted to Professor W. Waagen by Mr. C. L. Griesbach, Director of the Geological Survey of India, by whom I was entrusted with the task of working them out. I may here mention that a similar distinction had been conferred upon me by him in connection with the fossils of the Trichinopoli district. Further, I am indebted to Messrs. Noetling and Warth, who selected these fossils for despatch.

As the number of new, palæontologically important, species is very small in the whole collection, as moreover its principal interest is of a purely stratigraphical nature, I consider it expedient to begin with the geological part and to give the palæontological descriptions as an appendix.

1. THE STRATIGRAPHICAL DIVISIONS OF THE CRETACEOUS OF PONDICHERRI AND THEIR FOSSIL CONTENTS.

Dr. H. Warth distinguished during his researches into the cretaceous deposits of the Pondicherri district six different horizons (A—F), which dip slightly towards the east and are separated from the crystalline region to the west by a band of alluvium. The area which they occupy is rather small (eight miles by four) and moreover mostly covered by arable and garden land.

The horizon A (base) does not come into consideration in our stratigraphical researches, as no fossils are known in it except fossil wood and traces of worms. Thus there remain only the five other horizons, which have produced the whole of the Pondicherri fauna known up to the present time. It has been proved, it is true, by the examination of the fossil material, that the several horizons do not form independent palæontological zones, but that band B and C, as well as band D and E are connected together. Nevertheless they each possess special petrographical characters, which had to be the more carefully investigated by Dr. Warth, because it was believed at that time that the Utatúr stage (cenomanian) and Ariyalúr stage (senonian) were represented in the Pondicherri district, and thus it was to be hoped that in one of the horizons the presence of the equivalents of the Trichinopoli stage could be verified.

Of the horizons established by Warth, the two lower (B and C), correspond

[1] F. Kossmat: Ueber die Bedeutung der S. indischen Kreideformation, etc.: Jahrb. k. k. geol. Reichsanstalt, Wien, XLIV, 1894. Pt. 3, p. 461; translated in Rec. Geol. Sur. Ind., XXVIII 1895, p. 41. (The translation of some passages is not quite correct.)

[2] Dr. H. Warth: The Cretaceous formation of Pondicherry: Rec. Geol. Surv. Ind., XXVIII, 1895, pp. 15—21.

with the Valudayur stage of Blanford, the three upper comprise the bed which Blanford and Stoliczka considered as the equivalent of the Ariyalúr stage. But as, according to the results of the present researches, the Valudayur beds also come within the range of the Ariyalúr stage, the recognizable divisions of the cretaceous in the Pondicherri district can only be designated as substages.

I apply to them the following designations[1] :—

C.—Nerinea Beds = Horizon F of Warth.

B.—Trigonoarca Beds = Horizons D and E of Warth.

A.—Valudayur beds, of Blanford (Anisoceras beds) = Horizons B and C of Warth.

1. Valudayur (Anisoceras) beds ; Horizons B and C of Warth.

These beds have yielded the most numerous and best preserved fossils, among them a great number and variety of ammonite forms, and not only for this reason, but also on account of the still undecided question of age they were the most interesting division of the Pondicherri cretaceous.

The characteristic rock of the Valudayur beds (horizon C) is a very hard, fine grained, calcareous shell-sandstone of bluish or brownish colour, which bears much resemblance to the lumachelle of Garudamangalam ("Trichinopoly marble"). This rock does not form a continuous band, but only occurs in concretionary masses which are embedded in loose sands.

The fossils, mostly small gastropods and bivalves, are so abundant in the rock that one can often make out more than a dozen different species in a hand specimen. Their state of preservation is, as a rule, excellent, the fossils are almost throughout provided with the shell ; the ammonites generally show the pearly layer, and in the other molluscan shells there are very often remains of the original colour.

It is natural that this in every respect remarkable horizon should be almost exhausted by the different collectors, so that of the splendid ammonites which formed the chief ornament of the Forbes collection almost nothing now remains—even Blanford found the formerly numerous species represented by only a few specimens. It was therefore of great importance to me that this deficiency in the new collections was made good by a comparison with the collection described by Forbes.

The species most frequently occurring in the fauna of the Valudayur beds, and found in almost every large rock fragment are the following : *Anisoceras, sp. pl.*, *Baculites vagina*, Forb., *Rostellaria palliata*, Forb., *Turritella pondicherrensis*, Forb., *Dentalium arcotinum*, Forb., *Trochus arcotensis*, Forb., *Solariella radiatula*, Forb., *Pholadomya lucerna*, Forb., *Pharella delicatula*, Stol., etc.

The ammonite fauna of the Valudayur beds is characterized by a variety and abundance of species of *Phylloceratidæ* and *Lytoceratidæ* otherwise rarely to be met with, as among 34 species 20 belong to these two groups. Of *Lytoceras*

[1] F. Kossmat: Untersuchungen über die Südindische Kreideformation : Beiträge zur Geologie und Palæontologie Oesterr. Ungarns und des Orients, IX, Heft iii, iv, Wien, 1895, p. 102 (6).

itself 3 subgenera are represented, whilst among the aberrant forms of this family *Anisoceras* and *Baculites* predominate and occur in great abundance. The other ammonite groups are—with the exception of *Pachydiscus*—represented only by one or two species each. (Compare the general list of fossils.)

Much less remarkable, faunistically as well as petrographically, is the lower part of the Valudayur beds (Warth's Horizon B), which consists of yellowish sands and light coloured, fossil-bearing concretions. All the fossils collected by Dr. Warth in this, as it would seem formerly unknown horizon, are identical with species of the typical Valudayur beds (horizon C), and the horizons B and C may therefore unhesitatingly be put together as a single palæontological zone.

As the horizon of the Valudayur beds is easily recognized by its petrographical characters, I made the attempt when investigating the Forbes collection to collate the fossils belonging to those beds. It was thus seen that the species considered by Stoliczka as characteristic of the Utatúr stage appear associated with typical fossils of the Ariyalúr stage, and I think it is not superfluous to enumerate here some examples of the association of Valudayur species in the Forbes collection. I found the following species associated together in one and the same rock specimen:

(1) *Puzosia rembda*, Forb. (large example), with *Anisoceras indicum*, Forb.
(2) *Rostellaria palliata*, Forb. (A), *Pugnellus uncatus*, Forb. (A), and *Puzosia rembda*, Forb. (small example), with *Baculites vagina*, Forb. (A).
(3) *Anisoceras largesulcatum*, Forb., with *B. vagina*, Forb. (A).
(4) *Pachydiscus crishna*, Forb., with *B. vagina*, Forb.
(5) *Ficulopsis pondicherrensis*, Forb. (A), with *B. vagina*, Forb.
(6) *Phylloceras surya*, Forb., with *Ptychoceras sipho*, Forb.
(7) *Ammonites (n. g.) brahma*, Forb. (A), with *Ptychoceras sipho*, Forb.
(8) *Lytoceras indra*, Forb., with *Cerithium scalarioideum*, Forb. (A).
(9) *L. indra*, Forb., with *Anisoceras subcompressum*, Forb., and *Rostellaria palliata*, Forb. (A).
(10) *Anisoceras indicum*, Forb., with *Stigmatopygus elatus*, Forb. (A).

[The species marked (A) are found in the typical Ariyalúr stage of Trichinopoli.]

The matrix is invariably the same; that is, a hard, bluish shell-sandstone, which is filled with the characteristic small molluscan shells of the Valudayur beds. All the ammonites of the Forbes collection and a great number of gastropods and bivalves occur in this horizon. (Compare the general list of fossils.) Also most of the Pondicherri species described by Stoliczka occur, according to his notes on their matrix (bluish or brownish calcareous sandstone), in the same beds. He was however somewhat uncertain as to their horizon. Whilst, it is true, the ammonites are marked "Valudayur Group," the gastropods and bivalves of Ariyalúr type, occurring in the same matrix, are mostly attributed to the Ariyalúr, rarely to the Valudayur, stage, a circumstance which emphasizes Stoliczka's doubts as to the stratigraphical position of the Valudayur beds.

In the following special list of the fossils represented in Warth's collection, I could not indicate the localities one beside the other on account of their great

number (13). I have therefore arranged them in four columns (Rautankupam, Tutipet, Vanur, Pulichapalaiam), and marked them with Greek letters as follows.

Fossils of the Valudayur (Anisoceras) beds. Coll. Warth.

Rautankupam . . .	α = Rautankupam . . .	Horizon C
	β = ½ mile NW of Rautankupam	„ C
	γ = ½ mile NW of „ „ .	„ C
	δ = 1 mile NW of „ „ .	„ C
	ϵ = ½ mile NNE of „ „ .	„ C
Tutipet	α = 1 mile NNW of Tutipet . .	„ C
	β = ½ mile NW of „ . .	„ C
	γ = NNW of „ . .	„ C
	δ = ½ mile N of „ . .	„ C
	ϵ = 1 mile N of „ . .	„ C
	ζ = N of „ . .	„ C

Fossils.	Horizon C.		Horizon B.	
	Rautankupam.	Tutipet.	1 mile SE of Vanur.	1 mile SSE of Pulichapalaiam.
Lytoceras (Gaudryceras) kayei, F. .	...	δ		
Lytoc. (Pseudophyllites) indra, F. .	...	β?	...	×
Anisoceras indicum, F. . . .	...	α, γ, δ		
„ *subcompressum*, F. . .	...	δ, ζ		
„ *tenuisulcatum*, F. . .	...	α, δ		
„ *undulatum*, F. . .	...	α		
Ptychoceras sipho, F. . . .	...	α		
Baculites teres, F.	ϵ	δ		
„ *vagina*, F. . . .	γ	$\alpha, \gamma, \delta, \epsilon$	×	
„ *vagina*, var *otacodensis*, Stol.	δ	...		
Pachydiscus egertoni, F. . .	...	α		
„ *ganesa*, F. . .	...	δ		
„ cf. *gollevillensis*, Orb. .	...	δ		
Desmoceras diphylloide, F. . .	β	...		
Pugnellus uncatus, F. . . .	ϵ	γ, δ		
Rostellaria palliata, F. . . .	β	β, δ, ζ		
Athleta purpuriformis, F. . .	β	α, β, δ		
Velutilithes radula, F. . . .	β	δ		
„ *muricata*, F. . .	...	δ		
Lyria granulosa, Stol. . . .	...	δ		
Gosavia indica, Stol. . . .	ϵ	δ		
Turritella pondicherrensis, F. .	α	$\alpha, \beta, \gamma, \delta$		
„ *warthi*, Koss. . . .	...	α, β, δ		

FOSSILS.	HORIZON C.		HORIZON B.	
	Rautan-kupam.	Tutipet.	1 mile SE of Vanur.	1 mile SSE of Pulicha-palaiam.
Nerita divaricata, Orb.	γ			
Euspira pagoda, F.	ε	γ, δ		
" *rotundata*, ? Stol.	...	γ		
Trochus arcotensis, F.	...	α, β, γ, δ		
Solariella radiatula, F.	...	α, β, γ, δ		
Teinostoma cretaceum, Orb.	...	δ		
Ringicula labiosa, F.	...	α		
Trochactæon curculio, F.	...	α		
Bullina cretacea, Orb.	...	α, γ, ?		
" *sp.*	...	δ		
Dentalium arcotinum, F.	α, ε	α, β, γ, δ		
" *crassulum*, Stol.	...	α		
Corbula parsura, Stol.	...	δ		
" cf. *striatuloides*, F.	...	γ		
Neæra mutua, Stol.	...	γ	...	×
Corimya pertusa, Stol.	...	δ		
Ceromya subsinuata, F.	ε			
Pholadomya lucerna, Stol.	...	α, γ, δ	...	×
Panopæa orientalis, Stol.	β	...	...	×
Siliqua limata, Stol.	...	γ, δ		
Pharella delicatula, Stol.*	...	α, γ, δ	...	×
Tellina pondicherrensis, F.	...	δ		
" *forbesiana*, Koss.	...	α, β		
Baroda elicita, Stol.	α	...	...	×
Cardium cf. *pullatum*, Stol.	...	γ		
Protocardium bisectum, F.	α	δ		
Lucina fallax, F.	...	δ		
Yoldia striatula, F.	...	γ		
Axinea subauriculata, Orb.	...	β, δ		
Macrodon yapeticum, F.	...	α		
Trigonoarca galdrina, Orb.	...	α, δ ?		
" *abrupta*, F.	γ			
Modiola polygona, F.	α	α		

* A fine specimen found three quarters of a mile SE of Wottai, together with *Turritella* cf. *pondicherrensis*, Forb., Horizon C.

Fossils.	Horizon C.		Horizon B.	
	Rautankupam.	Tutipet.	1 mile SE of Vanur.	1 mile SSE of Pulichapalaiam.
Modiola flagellifera, F.	...	γ, δ		
Pinna arata, F.	...	ϵ		
Exogyra ostracina, Lam.	β	α		
Alectryonia ungulata, Schl.	α, β	δ	×	
Anomia sp.	...	α		
Lunulites sp.	...	α		
Stigmatopygus elatus, Forb.	γ			
Serpula filiformis, Sow	...	β		

2. *Trigonoarca beds (horizons D and E of Warth, Arrialoor Group of Blanford, in part).*

The *Trigonoarca beds*, which I have thus named on account of the abundance of *Trigonoarca galdrina*, Orb., are easily distinguished from the underlying Anisoceras beds by their petrographical structure.

They consist in their lower parts (horizon D) of very soft, friable sand and clay, of yellowish white colour, which preserve the fossils for the most part in the shape of casts. Ammonites are very rare, and many of the small gastropod and bivalve types which characterize the Valudayur beds have disappeared, probably because the rock is not favourable for their preservation. On the other hand *Nautilus* is found pretty often, whilst among the bivalves certain genera, especially *Ostrea* (*Exogyra, Alectryonia*) and *Trigonoarca*, appear in great numbers. The infilling of the fossils is very often a dark brown to black phosphate of lime, which is frequently also imbedded in the light coloured sand in the shape of irregular concretions.

Shark's teeth are not unfrequently met with in this horizon.

The upper Trigonoarca beds (horizon E), which, for example, are well developed in the neighbourhood of Rayapudupakam, likewise contain numerous phosphatic concretions in a fairly soft sandy clay matrix, which can scarcely be distinguished from that of the Ariyalúr beds near Otacod. In some places concretionary layers of hard, fine grained sandstone are met with in the horizon E, containing numerous, well preserved bivalves (*Trigonoarca galdrina*, Orb.) and sometimes show sections of corals (*Cyclolites filamentosa*, Forb.).

The distinction between Warth's horizons D and E is often rather difficult on account of the similarity of the structure of the rock composing them. Further, one finds in comparing the faunas of the D and E localities, that all the more abundant and remarkable species are common to both, and that on the whole only three of the rarer species of gastropods of the horizon E have not yet been recognized in the lower beds of Pondicherri.

I am therefore quite justified in regarding the two horizons D and E as a stratigraphical unit. Nevertheless I have made use in the following list of all the localities indicated by H. Warth, so that the opportunity is offered to every one to compare the faunas of each locality and to become convinced of their concordance.

The following species belong to the more abundant fossils of the Trigonoarca beds: *Turritella breantiana,* d'Orb., *Nerita divaricata,* d'Orb., *Cypræa sp. pl., Rostellaria palliata,* Forb., *Macrodon japeticum,* Forb., *Trigonoarca galdrina,* d'Orb., *Exogyra ostracina,* Lam., *Alectryonia ungulata,* Schloth. Specimens of silicified wood, which had evidently floated from the neighbouring land, are also not uncommon.

The Trigonoarca beds are also represented in the Forbes collection by remarkable fossils, which are all imbedded in a light yellowish, soft, sandy matrix. Among them are to be found, for example, *Turritella breantiana,* d'Orb., *Cypræa kayei,* Forb., *C. cunliffei,* Forb, *C. newboldi,* Forb., *Euspira pagoda,* Forb., *Spondylus calcaratus,* Forb., and some other species.

Blanford collected several fossils in the Trigonoarca beds, especially in the neighbourhood of Rayapudupakam and Saidarampet. The ammonite *Lytoceras (Pseudophyllites) indra,* Forb., formerly known only from the Valudayur beds, is of special importance among the fossils collected by him at Rayapudupakam. Stoliczka doubted the correctness of this locality, and gave to the specimen figured on pl. LVIII, figure 2, only the locality indicated "Pondicherry." I had the opportunity of examining this specimen and found that not only the soft, yellowish, sandy matrix, but also a *Turritella breantiana,* d'Orb. (not known in the Valudayur beds), attached to it shows the correctness of Blanford's locality.

The number of species which Stoliczka described from the Trigonoarca beds (mostly with the observations "soft, whitish sandstone," Ariyalúr beds) is not very large; the greater number of them are also represented in Warth's collection.

Fossils of the Trigonoarca beds. Coll. Warth.

Rautankupam	α= ¼ mile W of Rautankupam	Horizon D
	β= ¼ mile WNW of „	„ D?
	γ= 1 mile NNE of „	„ E?
Tutipet	α= ½ mile WSW of Tutipet	„ D
	β= ¼ mile WSW of „	„ D
	γ= W Slope of Tutipet ridge	„ D?
Karasur	α= Karasur	„ D
	β= ¼ mile NNW of Karasur	„ D
	γ= ½ mile NNW of „	„ E
	δ= ¼ mile N of „	„ D
	ϵ= ½ mile N of „	„ D
	ζ= Karasur ?	„ E?
Rayapudupakam	α= Rayapudupakam tank	„ E
	β= W. of Rayapudupakam	„ E
Saidarampet	α= 1 Saidarampet	„ E?
	β= 1 mile N of Saidarampet	„ E
	γ= 1 mile NW of „	„ E?
	δ= ¼ mile WNW of „	„ E?
	ϵ= Saidarampet ? „	„ E?

	Rautankupam.	Tutipet.	Karasur.	Rayapudupakam.	Saidarampet.	¼ mile N of Wattampalaiam (Horiz. E.)
Otodus sp. pl.	α	...	δ			
Am. (*n. g.*) *brahma*, F.	...	...	...	...	ε	
Pachydiscus gollevillensis, Orb.	α					
Baculites vagina, F.	α	...	δ	ε		
Nautilus n. sp. (*clementinus*, Blanf.)	...	...	β	...	β	
Nautilus sublævigatus, Orb. var.	...	...	ζ			
Belemnites fibula, F.	β					
Pugnellus uncatus, F.	α					
Rostellaria palliata, F.	α	α	...	α		
Cypræa kayei, F.	...	...	...	α		
„ *cunliffei*, F.	α					
„ *newboldi*, F.	...	α	δ	α		
Gosavia indica, Stol.	...	...	...	α		
Volutilithes muricata, F.	α					
„ *radula*, F.	...	...	ζ			
Murex fluctuosus, F.	α					
Trichotropis sp.	...	α				
Cerithium karasurense, Koss.	...	...	α			
Turritella breantiana, Orb.	...	α	...	...	ε	
„ cf. *pondicherrensis*, F.	...	...	...	α	α	
Scala cf. *turbinata*, F.	...	α				
Euspira pagoda, F.	α	...	...	...	...	×
Nerita divaricata, Orb.	...	...	β	...	ε	
Euptycha larvata, Stol.	...	...	...	α		
Ceromya subsinuata, F.	...	...	β	...	α	
Pholadomya lucerna, F.	α, β	β				
Panopæa orientalis, F.	...	...	...	α		
Cyprina cristata, Stol.	α					
Hippagus æmilianus, Stol.	α					
Macrodon japeticum, F.	α	α, β, γ	β, γ	...	ε	
Trigonoarca galdrina, F.	α	α, β	β, γ	α	α, β	
„ *abrupta*, F.	...	...	...	α		
Nucula sp. ?	...	β				
Protocardium bisectum, F.	...	...	...	...	β	
Spondylus calcaratus, F.	α					
„ *ariyalurensis*, Stol.	...	α				

	Rautan-kupam.	Tutipet.	Karasur.	Raya-pudu-pakam.	Sai-daram-pet.	½ mile N of Wat-tampa-laiam (Horiz. E.)
Spondylus lamellosus, Koss.	α	α	...	...	ϵ	×
Plicatula septemcostata, F.	...	α				
Exogyra ostracina, Lam.	α, β, γ	...	β	α, β	ϵ	×
Ostrea sp.	α, β					
Alectryonia ungulata, Schl.	α	α	γ	α, β	α, γ, ϵ	
Terebratula arabilis, F.	α	α				
„ *biplicata*, Sow.	α					
Hemiaster pullus, Stol.	α					
„ *tamulicus*, Koss.	α					
Cyclolites filamentosa (?) F.	...	β				
Fossil wood	...	α	ϵ	...	γ, δ	

3. Nerinea beds (Horizon F of Warth, Arrialoor group of Blanford, in part.)

The Trigonoarca beds are overlaid by a yellowish, very calcareous, coarse grained sandstone, which contains here and there limestone nodules, and forms the only continuous hard bed in the Pondicherri cretaceous. Blanford and Warth mention peculiar cylindrical bodies occurring in it. The fauna of this bed is distinguished, according to the species which I have before me, principally by the presence of large specimens of *Nerinea*, *Nautilus*, and vast numbers of *Foraminifera* (especially *Orbitoides*), filling the hard matrix of the greater fossils.

Some species (corals, *Teredo*, *Ostrea*) occur in the loose sands which, according to Warth's communication, overlie the hard, calcareous stratum.

The horizon, called here Nerinea beds, was already known to Mr. H. F. Blanford (although no *Nerinea* seems to have been found by him), but he united it with some other fossiliferous beds (called in this paper Trigonoarca beds) as one division, which he identified with the Ariyalúr stage. The establishment of the Nerinea beds as a separate horizon is practically the only difference between Blanford's scheme of the Pondicherri cretaceous and that adopted in this paper.

Nautilus danicus, Schloth., *N. serpentinus*, Blanford, and *N. sphæricus*, which were described by Blanford from Rayapudukapam and Saidarampet, may with certainty be ascribed to the Nerinea beds, occurring in these localities above the Trigonoarca beds, the more so as from Saidarampet, from Warth's horizon F, the two latter species are actually lying before me.

This uppermost fossil-bearing horizon is very little represented in Forbes's collections; to it belong probably *Nautilus sphæricus*, F., *Caryophyllia arcotensis*, F., and the peculiar *Nautilus* (*Aturia*) *delphinus*, F., which is not to be found in the more recent collection.

Fossils of the Nerinea beds. Coll. Warth.

Nautilus serpentinus, Blanford .	Saidarampet.
" *sphæricus*, Forbes . .	Saidarampet, 1½ mile SSE of Valudayur (Usteri canal), E of Wottai ?
" *tamulicus*, Koss. . .	Saidarampet, Kadaperikupam ?
Nerinea sp.	1½ mile SSE of Valudayur (Usteri canal).
Cerithium cf. *karasurense*, Koss. .	Saidarampet.
Teredo glomerans, Stol. . .	1 mile SSE of Valudayur (Usteri canal), ¾ mile SW of Tutipet, ¾ mile WSW of Trumbai.
Ostrea sp.	Saidarampet, ¾ mile NW of Trusitambalam.
Cyclolites conoidea, Stol. . .	Saidarampet, ½ mile SW of Tutipet.
Turbinolia arcotensis, Forbes . .	1 mile SSE of Valudayur (Usteri canal), ¾ mile NW of Trusitambalam.
Orbitoides sp.	SSE of Valudayur; Saidarampet (Usteri canal).
Amphistegina sp ? . . .	SSE of Valudayur (Usteri canal).

4. *Faunistic affinities between the three divisions of the Pondicherri cretaceous.*

The faunistic isolation of the Valudayur beds, as compared with the upper beds, is not so great as was formerly assumed, and the above lists of fossils show a pretty large number of species which extend from Warth's horizon B, to the horizon E, or, in other words, from the lower Valudayur beds to the upper Trigonoarca beds. Out of 46 species from the Trigonoarca beds in Warth's collection, 18 are also known in the Valudayur beds, among them very characteristic examples, as *Am. brahma*, *Baculites vagina*, *Pugnellus uncatus*, *Rostellaria palliata*, etc. *Am. brahma*, which occurs in the shell sandstone of the Valudayur beds associated with species of *Anisoceras* and *Ptychoceras sipho*, was found in a rock specimen from Saidarampet with a phosphatized cast of *Macrodon japeticum* and a *Turritella breantiana*. *Lytoceras indra*, of which Forbes met with numerous specimens from the Valudayur beds and which was also found by Warth in the horizon B, was collected by Blanford in the Trigonoarca beds of Rayapudupakam. The most abundant species of the latter beds, as, for example, *Trigonoarca galdrina*, *Macrodon japeticum*, *Exogyra ostracina*, *Alectryonia ungulata*, are also not unknown in the lower beds, and the similarity would be still greater, if small gastropods and bivalves, which are found so abundantly in the Valudayur beds, were more suitable for preservation in the Trigonoarca beds.

But, in any case the fact of greatest importance is that three of the four ammonites known in the Trigonoarca beds are identical with species of the Valudayur beds. The fourth is nearly related to *Pachydiscus crishna*, Forb., so that the animal group, upon which the most sharply defined zonal divisions are generally based, gives here no aid in making a distinction founded upon palæontological and stratigraphical grounds. The distinction between the two beds abovenamed seems on the whole to be traceable to their different facies, and it is there-

fore not very probable that they will be easily recognized outside the Pondicherri district.

The fauna of the Nerinea beds, which certainly up to the present time is very little known, seems to have a much more independent position.

2. RELATIONS BETWEEN THE CRETACEOUS DEPOSITS OF THE PONDICHERRI AND TRICHINOPOLI DISTRICTS.

1. *Relations to the Utatúr stage (Lower division of the cretaceous of Trichinopoli).*

Stoliczka tried to show that the ammonite fauna of Pondicherri did not indicate neocomian, but was much more nearly related to that of the Utatúr stage, and even had a number of species in common with it. The Valudayur beds were on that account looked upon as their equivalent division, that is to say, as cenomanian. It is therefore necessary to examine the species, on which this determination of the age, corresponding so little with the otherwise intimate connection of the Ariyalúr and Valudayur beds, was based. Such a comparison between the formerly identified species of the Utatúr and Valudayur beds can only be very briefly indicated in the following statement; for details I must point to the revision of the cretaceous fauna of Southern India, of which the first part has already appeared.[1] :—

A.—VALUDAYUR BEDS.	B.—UTATÚR STAGE.
Phylloceras nera, Forb.	*Phylloceras velledæ,* Mich., with which Stoliczka (Records, I., p. 34) identified the *Phyll. nera,* possesses more inflated sides, less complicated sutures, and shows no constrictions in the umbilical region (cf. Kossmat: Untersuchungen über die s. ind. Kreide, p. 109).
Phylloceras forbesianum, d'Orb.	With *Phyll. forbesianum,* Orb. (= *rouyanum,* Forb., *non* d'Orb.) was identified a form from the Utatúr stage by Stoliczka, and with some reservation by myself (cf. Kossmat: loc. cit., pp. 111, 158). Nevertheless there are some differences which appear to be of specific importance. The Utatúr examples are more strongly inflated and do not show the funnel-shaped depression around the umbilicus so distinctly; the saddles of the sutural line are more prominent than in the Pondicherri species, and the siphonal lobe is simply lancet-shaped, whilst it is greatly indented in *Phyll. forbesianum*. My attention was drawn to these differences only when Mr. J. F. Whiteaves had sent me from the Nanaimo stage of

[1] F. Kossmat, Untersuchungen über die südindische Kreideformation, I Theil: Beiträge zur Geologie und Palæontologie Oesterreich-Ungarns und des Orients. Herausgegeben von Prof. Dr, W. Waagen, IX, Heft iii, iv, Wien, 1895.

the Georgia Straits, British Columbia, a *Phylloceras* which corresponds well with the Valudayur species but is to be distinguished from the Utatúr species on account of the characters mentioned of the latter.

Lytoceras (Gaudryceras) varuna, Forb. — Stoliczka's specimen differs in the absence of a distinct umbilical wall, and in the larger size of the second lateral saddle (*Lyt. odiense*, Kossmat, loc. cit., p. 129).

Lyt. (Gaudryceras) kayei, Forb. — *Lyt. kayei*, Stol.=*Lyt. vertebratum*. Kossm., loc. cit., p. 126) is distinguished by its rapidly increasing whorls and the completely flattened periphery in the middle period of growth.

Lyt. (Tetragonites) cala, Forb. — *Lyt cala*, Stol. (=*L. kingianum*, Kossm., loc. cit., p. 136) increases rapidly, is much more involute than the Pondicherri species and has an oval (not quadrate) cross section.

Hamites (Anisoceras) indicum, Forb. — =*An. subcompressum*, Stol.; from Odiam; only mentioned but not figured (Kossmat: loc. cit., p. 145).

Ham. (Anisoceras) subcompressum, Forb. (*An indicum*, Stol.) — The examples from Odiam are not flattened on the sides, and are without constrictions (Kossmat: loc. cit., p. 145).

Hamites (Anisoceras) nereis, Forb. — *An. nereis*, Stol., is distinguished from the Pondicherri species by its cross section and sculpture. The groove on the periphery is not structural, as in the type, but occurs only through the removal of the siphon, for the ribs run uninterruptedly over the periphery in many places (Kossmat: loc. cit., p. 148).

Baculites teres, Forb. — The example from Odiam is distinguished by the possession of annular swellings and is very probably not a *Baculites*, but a fragment of a *Hamites* (*Plychoceras*?) (Kossmat : loc. cit., p. 154).

Desmoceras diphylloide, Forb. — Stoliczka describes this species from Odiam, but I have only before me examples, which come from the white sandstone of the Ariyalúr stage from Otacod.

Puzosia rembda, Forb. (synon. *P. durga*, Forb.). — *Ammonites durga*, Stol., from the Utatúr stage is distinguished by the difference in the form of the constrictions, by the absence of a keel, and by the more complicated suture.

Belemnites fibula, Forb.	*B. fibula*, Blanford, is quite different from the Pondicherri species (which does not occur in the Valudayur beds, but in the Trigonoarca beds) in the character of its cross-section (cf. the palæontological part of this paper).
Desmoceras jama, Forb.	The large, fine ammonites, which were identified by Stoliczka first with *Desmoceras beudanti*, d'Orb., then with *D. jama*, cannot be compared with this small, unornamented form, of which it cannot be said with certainty, whether it is a typical *Desmoceras* or a *Puzosia*.
Natica munita, Forb.	*Vanikoro munita*, Stol., is quite distinct from the Pondicherri species. In the latter the flat band is bordered along the suture by a sharp edge, near which the sides are slightly concave. Moreover the mouth is considerably widened laterally, as in *Gyrodes tenellus*, Stol.
Tellina pondicherrensis, Forb.	*Baroda pondicherrensis*, Stol., is distinguished by the presence of radiating striæ and by the stronger concentric sculpture.
Protocardium bisectum, Forb.	The example figured by Stoliczka from Mongle-pady appears to be identical with the Pondicherri species, but it is to be observed that the *P. bisectum* reaches to the upper Trigonoarca beds, that is beds which undoubtedly belong to the Ariyalúr stage.
Trigonoarca gamana, Forb.	Stoliczka's example from the Utatúr stage is very contracted anteriorly, whilst in Forbes's original specimen the lower margin is parallel with the hinge line.

There are other species besides, which are said to occur in both the Ariyalúr and Utatúr stages of the Trichinopoli district; for example, *Lucina fallax*, Forb., *Solariella radiatula*, Forb., *Leptomaria indica*, Forb. (the identity of the specimens from the Ariyalúr stage with those from Pondicherri is only certain in the case of the two last named species). One Pondicherri species, *Axinea cardioides*, d'Orb., is mentioned as occurring in the upper Trichinopoli beds of Serdamangalam, as well as in the Utatúr stage. The ammonites are in the first place the chief factors in the solution of the question, and it has been shown in the revision, the results of which I have briefly mentioned above, that of the twelve formerly identified species, ten are certainly different, one cannot be taken into account, as it has not been figured and the other comes only from the Ariyalúr, not from the Utatúr stage.

But what is of greater weight than all this. is a circumstance of quite another kind, namely, the complete absence of all characteristic Utatúr species and genera in Pondicherri. Although the ammonite fauna of the Valudayur beds was so extraordinarily rich, not a single *Acanthoceras*, nor *Schloenbachia*, nor *Turrilites*, nor *Hamites* of the group of *H. armatus*, Sow., nor *Pusosia* of the group of *P. planulata*, Sow., etc., were found in it—all groups predominating in the Utatúr. What we find in Pondicherri, besides *Phylloceras* and *Lytoceras*, are chiefly species of *Pachydiscus* and other ammonite types of the uppermost cretaceous.

2. *Relations to the Trichinopoli stage.*

The ammonite fauna of the Valudayur beds is quite different from that of the Trichinopoli stage; but on the other hand, many nearly related, or even some identical species are found among the gastropods and bivalves. But as a study of the list of fossils shows, these are almost throughout such forms as extend upwards unchanged into the Ariyalúr stage in the Trichinopoli district. On the whole the boundary between the two groups is somewhat uncertain, and still requires some corrections. Typical species of the Trichinopoli group are entirely absent in the Pondicherri fauna, and this circumstance is so much the more important as, in consequence of the great similarity in the facies of the lower Trichinopoli stage and that of the Valudayur beds, the fauna is for the greater part composed of the same genera. Among the beautiful molluscs of the bluish lumachelle (shell-sandstone) of Garudamangalam the genera *Pugnellus*, *Solariella*, *Trochus*, *Turritella*, *Euspira*, *Dentalium*, *Bullia*, etc., play the same rôle as in the Valudayur beds, and even the species belonging to these genera resemble each other. In spite of this, cases of true identity are very rare.

3.—COMPARISON BETWEEN THE CRETACEOUS BEDS OF PONDICHERRI AND THE ARIYALÚR STAGE. (UPPER DIVISION OF THE TRICHINOPOLI CRETACEOUS.)

1. *Valudayur (Anisoceras) beds.*

Four characteristic species of the Ariyalúr stage are found in the ammonite fauna of this division, namely, *Pachydiscus egertoni*, *Amm.* (*n. g.*) *brahma*, *Desmoceras diphylloide*, *Baculites vagina*, var. *utacodensis*; in other respects also the two groups are conspicuous by the presence of certain types of ammonites as, for instance, certain *Pachydiscus* forms, and by the absence of others, which are very important in the Utatúr and Trichinopoli stages. The ammonite fauna of the Ariyalúr beds is, it is true, not very varied, and therefore does not offer many points of comparison.

The rich gastropod and bivalve fauna is, as the general list shows, almost perfectly identical with that of the Ariyalúr stage, for which reason Stoliczka began to doubt the accuracy of his earlier conception based on the ammonites. Two localities, Parcheri and Kalligadi, which lie on the boundary line between the Trichinopoli and Ariyalúr stages and were first ascribed to the former, show such a striking similarity of their fauna to that of the Valudayur beds, that they may be completely identified with them. In Parcheri *Neæra mutua*, Stol.,

Pholodomya lucerna, Forb., *Siliqua limata*, Stol., *Pharella delicatula*, Stol., and *Pugnellus uncatus*, Forb., occur, besides a few other species. Still greater is the analogy in Kalligadi, which also seems to have in the facies of its fossils great resemblance to the Valudayur beds (Stoliczka, Cret. S. India, Vol. II., p. 96), and as well as these must belong to the Ariyalúr stage.

Warth's horizon B., the base of the Valudayur beds, already contains a true Ariyalúr fauna, and affords a strong proof of the accuracy of the decision come to as to age of the beds.

2. *Trigonoarca beds.*

The great similarity between the Ariyalúr stage and the Pondicherri beds is quite as distinctly recognizable in this division, whose gastropod and bivalve fauna is almost completely identical with that of the former. This similarity is the more remarkable, as the argillaceous sands which characterize the higher Ariyalúr beds also predominate in the Trigonoarca beds. The similarity is so great that specimens from Ariyalúr, etc., can often not be distinguished by their matrix from examples from Pondicherri. In the Trichinopoli district peculiar argillaceous beds occur, full of numerous sharp casts of bivalves, which, according to Blanford (Mem. Geol. Surv. India, IV, p. 135), constitute a peculiar feature of the Ariyalúr stage. According to the description, there is no doubt that these argillaceous sands are the same as those occurring in the Trigonoarca beds of Rautankupam and Tutipet, where they contain numerous casts of *Trigonoarca galdrina*. The soft yellowish white sands of Otacod, which alternate with these argillaceous sands are again indistinguishable from the sands occurring in the localities of the Pondicherri district mentioned above, where they are also in close relationship with the argillaceous beds. This striking similarity of the facies and fauna could not escape the attention of Blanford and Stoliczka, and therefore we find this horizon always given as the equivalent of the Ariyalúr stage. It is a pity that the latter could not be so distinctly subdivided in the Trichinopoli district as the corresponding beds in Pondicherri, but it seems that there also the localities corresponding in their fauna to the Valudayur beds occur somewhat lower in the series than the others ; that, for example, the beds of the localities Parcheri, Kalligadi, Karapadi, lying at the base of the Ariyalúr stage, agree best with the Valudayur beds, whilst the stratigraphically higher localities Ariyalúr and Otacod are to be correlated with the Trigonoarca beds by their facies and in their fauna. But as the faunas of these two horizons in the Pondicherri district evidently blend into one another, so also is this the case in the Trichinopoli district. *Ammonites brahma*, *Baculites vagina*, var *otacodensis*, and numerous gastropods and bivalves of the Valudayur beds occur also in the higher beds of the Ariyalúr stage immediately under the massive sandstone complex of the middle zone (Blanford, p. 138), which has yielded no fossils except some reptilian bones.

3. *Nerinea beds.*

Ammonites are absent in this division but, besides large examples of *Nerinea*, some species of *Nautilus* occur, among the latter a very interesting European form, *Nautilus danicus*, Schloth. Foraminifera, especially *Orbitoides*, appear in

vast numbers and fill the matrix of the larger fossils. Thus the analogy with the beds near Niniyur (Trichinopoli district), where *N. danicus* and *Orbitoides* are found, and ammonites are absent, is apparent.

In the Trichinopoli district, as H. F. Blanford pointed out, the Niniyur beds are distinctly separated from the fossiliferous strata near Ariyalúr by the massive sandstones mentioned above. Almost all fossils are peculiar to them and completely different from those of the typical Ariyalúr beds, a difference which is so apparent that it had already been observed by Mr. H. F. Blanford before the fauna had been studied in detail and looked upon as a matter of great importance. From the absence of ammonites and the occurrence of *Nautilus danicus* he concluded that the Niniyur beds represent the topmost division (danian) of the cretaceous system, a view which has proved to be the correct one. But as he did not formally make these beds a separate division, the Niniyur fossils have been dealt with in Stoliczka's Memoir simply as Ariyalúr fossils, so that the significance of this horizon has become less striking. H. Leveillé, who did not study these beds in the field, proposed, therefore, to give them the name Niniyur stage.[1] A point of great importance, which urgently needs explanation, is the appearance of large specimens of *Nerinea* in the beds of Niniyur (cf. Stol. II., p. 306, 301, 227, 221), which Blanford and Stoliczka have repeatedly drawn attention to, and these specimens are named in some places *Nerinea blanfordiana*. But in the description of this species only Maravattur and Paruli (Utatúr group) are mentioned as localities, whilst not a single *Nerinea* from Niniyur has been described. It seems as if there were some mistake here, the more so, as in different places examples of *Cypræa* in Niniyur have been expressly mentioned, but these also do not appear in the description of the species of this family. But if even the examples of *Nerinea* from Niniyur could be proved to be identical with those of the Nerinea beds, it would not be advisable to consider the two horizons as equivalent without further investigation. In the Trichinopoli district the Niniyur beds are separated from the true Ariyalúr beds by the abovementioned thick unfossiliferous formation, whilst in Pondicherri the Nerinea beds lie immediately above the equivalent of the typical Ariyalúr beds. For this reason it is quite possible that they correspond to the unfossiliferous division. The fact that species occur, which are also known in the lower beds (for instance, *Nautilus sphæricus, Teredo glomerans*) speaks in favour of this view, according to which the Nerinea beds would lie on the stratigraphical boundary between the Niniyur and Ariyalúr beds.

4. Conclusions.

From what has been said above it follows that the whole of the cretaceous series of Pondicherri falls completely within the Ariyalúr stage of Blanford, and that with great probability it begins with the same horizon as the latter (beds of

[1] *H. Leveillé* : Géologie de l'Inde Française. Bull. Soc. Géol. de France. 3me Serie, XVIII, 1889, p. 144 ff.; cf W. T. Blanford : On the papers of Dr. Kossmat and Dr. Kurtz, and on the ancient geography of Gondwanaland. Rec. Geol. Surv. Ind., XXIX, 1896, p. 51, referring to a passage in my paper, Jahrb. k.k. geol. Reichs Anstalt, 1894, where, when speaking shortly on the divisions of the Trichinopoli cretaceous, I only quoted the paper of Leveillé in connection with the Niniyur beds.

Parcheri, Kalligadi, etc.). From this results the interesting fact of a true overlap of the Ariyalúr stage, for which also many other proofs are forthcoming.[1]

Even in the Trichinopoli district the Ariyalúr stage overlaps the older strata and lies, for example in Olapadi, immediately upon the Utatúr group, and for a considerable extent even on the crystalline rocks. In the northern part of the Trichinopoli district the cretaceous disappears under the alluvium of the Vellar river; reappears in the Viruddháchallam area—there also the Ariyalúr stage only is present—is then again invisible, to reappear finally in the Pondicherri district once more in rich development.

This overlap of the Ariyalúr stage is of considerable interest, for it is repeated in areas far distant from India and seems to be of great importance in the Pacific area. It will probably be found in the highlands of Assam (N. E. Bengal), but I will not treat of this area whose cretaceous fauna, according to Stoliczka's opinion[2] bears a very great resemblance to that of Pondicherri, as the fossils belonging to it will be open to a more minute research in the near future.

III.—THE AGE OF THE PONDICHERRI BEDS.

On account of the recognized similarity of the Pondicherri deposits to the Ariyalúr stage, the determination of the age of the former, that is, the comparison with the European cretaceous deposits is proportionally an easy task, in the fulfilment of which the numerous ammonites are of special use. Of the latter very many are found, in the Valudayur beds, which are nearly related to species of the European senonian, while two species appear to agree exactly with such. These are: *Pachydiscus egertoni*, Forb., and *Lytoceras* (*Gaudryceras*) *kayei*, Forb., from which two species known in the upper senonian, *Pachydiscus neubergicus*, Hauer, and *Lytoceras planorbiforme*, Böhm, can scarcely be distinguished. As to the other species, their European representatives are, as the list shows, restricted solely to the upper senonian and belong partly even to the typical forms, as, for example, *Baculites anceps*, corresponding to *Baculites vagina*; *Hamites cylindraceus* Defr., which represents the Indian *Hamites rugatus*, Forb.; and *Scaphites constrictus*, Sow., to the relationship of which *Scaphites cunliffei*, Forb. belongs. Of great importance for the determination of the age of the beds are also the following species, *viz.*, *Sphenodiscus siva*, Forb. (cf. *S. ubaghsi*, Gross.), *Amm.* (*n. g.*) *brahma*, Forb. (cf. *A. haugi*, Seunes), *Puzosia rembda*, Forb. (cf. *P. fayoli*, Gross.) *Pseudophyllites indra*, Forb. (cf., *Ps. colloti*, Gross.), *Pachydiscus crishna*, Forb. (from the Group of *P. egertoni*, or *neubergicus*), etc. (see the general list).

Among the genera and subgenera in the ammonite fauna of the Valudayur beds (*Phylloceras*, *Gaudryceras*, *Tetragonites*[3] *Pseudophyllites*, *Anisoceras*, *Ptychoceras*, *Baculites*, *Sphenodiscus*, *Holcodiscus*, *Pachydiscus*, *Hauericeras*, *Desmoceras* *Scaphites*) not one—with the possible exception of *Ptychoceras*—is foreign to the European senonian, a circumstance which sufficiently proves, that the

[1] H. F. Blanford, Cret. of S. Arcot and Trichinopoly Districts: Mem. Geol. Surv., India, IV, Chap. VIII.

[2] F. Stoliczka, in H. B. Medlicott's Geological Sketch of the Shillong Plateau in N.-E. Bengal: Mem. Geol. Surv., Ind., VII, pt. i, p. 182, ff.

[3] M. A. de Grossouvre communicated to me that he had met with a species related to *Tetragonites cala*, Forb., in the French senonian.

apparent anomalies in the cretaceous fauna of Southern India has been dissipated since the corresponding European deposits have become better known.

The ammonite fauna of the Trigonoarca beds, consisting of four forms, shows the same relations as the fauna of the Valudayur beds; it has three species in common with the latter, the fourth, *Pachydiscus gollevillensis*, Orb., is a form recognized as occurring with *Pachydiscus neubergicus* in Europe.

Of much less importance for the determination of the age of the beds are the other animal groups, which, however, completely confirm the results attained by the aid of the ammonite fauna. They have likewise undoubted relationship with the European senonian. (For example, *Exogyra ostracina*, Lam., *Alectryonia ungulata*, Schloth., *Pholadomya lucerna*, Forb. (cf. *caudata*, Röm.), *Modiola flagellifera*, Forb. (cf. *flagellifera*, Zittel), etc.)

As to the Nerinea beds there is much less material at hand for the determination of their age; but their stratigraphical position, the complete want of ammonites, and the presence of *Nautilus danicus* permit of their being correlated, with great probability, with the European danian.

According to these results the Pondicherri beds may be regarded as the uppermost stages of the cretaceous system: the Valudayur and the Trigonoarca beds are equivalent to the upper senonian (campanian, mucronata beds), the Nerinea beds to the zone of *Nautilus danicus* (danian).

We obtain a confirmation of these conclusions in the investigation of the fauna of the Trichinopoli district, in which the whole of the upper cretaceous is developed. There also the cephalopod fauna of the Ariyalúr stage, so far as it can be compared with the European, shows a decided upper senonian character (*Pachydiscus otacodensis*, Stol. (cf. *colligatus*, Binkhorst), *P. egertonianus*, Forb. (cf. *neubergicus*, Hauer), *Baculites vagina*, Forb., var. *simplex*, Koss. (cf. *anceps*, Lam.) while in the upper part of the underlying Trichinopoli stage occur characteristic lower senonian species (for example, *Schloenbachia (Peroniceras) dravidica*, Koss. (cf. *tricarinata*, Orb.), *Placenticeras tamulicum*, Blanf. (cf. *syrtale*, Morton), and also the turonian and cenomanian (lower Trichinopoli and Utatúr stages) follow each other in the same order as in Europe. One is therefore justified in adopting the European divisions of the upper cretaceous for these deposits, and in going so far as to say that the Ariyalúr beds of the Trichinopo li and Pondicherri districts are not only to be considered as an approximate equivalent of the senonian (Stoliczka, Cret. S. India, Vol. IV, p. II.) but as representing a definite part of it, *viz.*, the upper senonian.

Seunes[1] states regarding the distribution of the uppermost stage of the Senonian as follows :—" D'apres l'analogie de la faune des *Ammonitidæ*, on est amené à regarder comme sensiblement synchronique des couches à *Pachydiscus jacquoti* des Pyrénées (Maëstrichtien); le Dordonien de l'Aquitaine; le Calcaire à Baculites du Cotentin; le Tuffeau de Maëstricht à *Ammonites* et à *Hemipneustes* (= partie supérieure des couches à *Belemnitella mucronata* de la Belgique), la partie supérieure des couches à *Belemnitella mucronata* d' Aix-la-Chapelle; la Craie de Limbourg; la craie de Lemberg (Galicie); la Craie à *Pachydiscus gollevillensis* d'Irlande; la partie supérieure des couches á *Ammonitidæ* du groupe

[1] Contributions à l'étude des céphalopodes : Mém. de la Soc. Géol. France. Paléontologie, Vol. II., 1891, p. 21.

de l'Arrialur de l'Inde anglaise et de Pondichérri." I have quoted this passage verbatim, because in it the correlation of the peculiar ammonite faunas of the upper campanian, the latest ammonite fauna known up to the present time, is precisely given, and the position of the Ariyalúr stage correctly indicated. But it may be pointed out with reference to the latter that not only the upper beds of the ammonite bearing Ariyalúr stage of Ariyalúr and Pondicherri, but also the lower beds, consequently the Valudayur beds, formerly considered as cenomanian, belong to this stage. Seunes rightly remarks further, that the similarity of the Indian and European deposits of this period is still more increased by the fact that they are in both regions immediately overlaid by the zone of *Nautilus danicus* in which ammonites are absent.

IV.—INDO-PACIFIC EQUIVALENTS OF THE ARIYALÚR STAGE IN PONDICHERRI.

Putting aside the cretaceous deposits of Assam, which, according to our present knowledge, seem to be nearly identical with the Pondicherri deposits, but still require a more minute study, there are within the area of the Indo-Pacific ocean the following cretaceous regions, which may be brought into close relationship with the Ariyalúr stage: Natal, Borneo, Yesso, Vancouver Island (and California), Quiriquina Island (Chili).

In Natal[1] the upper Trichinopoli and Ariyalúr stages are represented by numerous fossils; to the latter the following species specially point: *Puzosia* (*Hauericeras*) *gardeni*, Baily, *P.* (*Hauericeras*) *rembda*, Forbes., *Lytocerus* (*Gaudryceras*) *kayei* Forbes., *Anisoceras indicum*, Forbes, *Pugnellus uncatus*, Forbes, *Solariella radiatula*, Forbes., *Pollia pondicherriensis*, Forb., *Turritella breantiana*, Orb., all forms which frequently occur in the Ariyalúr stage of the Pondicherri and Trichinopoli districts.[2] From Madagascar, besides some *Ostreæ* of the senonian Ariyalúr stage[3] (for instance *Alectryonia ungulata*, Schl.), a *Turrilites* nearly related to *T. tuberculatus*, Bosc., *Baculites baculoides*, Lam., and an *Acanthoceras* belonging to the group of *A. rotomagense*, were recently brought to Europe, all the latter indicating cenomanian[4] species.

In Yesso, too, where, it is true, no division of the cretaceous was attempted, the Ariyalúr stage certainly does not occur isolated, for besides numerous species which are characteristic of it (for example, *Puzosia gardeni*, Baily, *Pachydiscus ariyalurensis*, Stol., *Pach. sp. pl.*, *Anisoceras largesulcatum*, Forbes., etc.,) there is also recognized a series of forms which are related to, or identical with, those of the Trichinopoli and Utatúr stages.[5]

[1] C. L. Griesbach, Geology of Natal: Quart. Journ. Geol. Soc. London, XXVII, 1871, p. 60 ff.; W. H. Baily, Description of some Cretaceous fossils from Southern Africa: *ibid.*, XI, 1855, p. 454 ff.

[2] F. Kossmat: Die Bedeutung der südindischen Kreideformátion: Jahrb. k. k. geol. Reichsanstalt, Wien, XLIV, 1894, Heft 3, p. 464-65.

[3] R. B. Newton: Quart. Journ. Geol. Soc. London, XLV, 1889, p. 333.

[4] M. Boule, Notes sur les fossiles rapportés de Madagascar, par M. E. Gautier: Bull. du Muséum d'histoire Naturelle. Paris. 1895. No. 5, p. 4.

[5] Compare the works upon Yesso, by M. Yokoyama: Palæontographica, XXXVI, Stuttgart, 1890; and K. Jimbo: Palæontologische Abhandlungen, Bd. VI, Heft 3, Jena, 1894.

In Borneo[1] only the Ariyalúr stage (with *Nautilus trichinopolitensis*, *Terebratula biplicata*, *Exogyra ostracina*, *Nerinea*, etc.) is known up till now, but an overlap of it cannot be recognized until the conditions there are better known.

The Ariyalúr overlap has been recently shown in the clearest manner by Steinmann in the Island of Quiriquina (Chili), which, as regards the occurrence of the cretaceous deposits, possesses a great resemblance to Vancouver Island. The cretaceous deposits of these two islands show a particularly interesting faunistic accordance with Pondicherri.

In southern Vancouver the Nanaimo stage immediately succeeds the folded palæozoic and crystalline rocks. This stage has typical senonian forms even in the lowest division (Division A and B, Richardson): for instance, *Pusosia gardeni*, Baily, *Pachydiscus newberryanus*, Meek, *Hamites obstrictus*, Jimbo. (aff. *rugatus*, Forbes.), *Baculites occidentalis*, Meek. A large number of the species pass up into the higher horizons, in which *Lytoceras indra*, Forbes., and *Lytoceras* aff. *kayei*, F. (= *jukesii*, Whiteaves[2]) are found; these are species quite characteristic of the Valudayur type. I had the opportunity at the British Museum in London of studying a collection of ammonite species from Vancouver which had not yet been worked out, and I found among them likewise only forms which pointed to a very high horizon of the upper chalk: *Lytoceras indra*, Forb., *Pachydiscus otacodensis* Stol., *Pach. newberryanus*, Meek, *Pachydiscus sp. nov.* aff. *tweenianus*, Stol., *Schloenbachia sp. nov.*, *Hamites obstrictus*, Jimbo, *Heteroceras* aff. *cooperi*, Meek, *Baculites occidentalis*, Meek, etc. All the specimens are found in greyish black, tough, somewhat splintery concretions and are mostly beautifully preserved. The occurrence of the two species *Lytoceras indra* and *Pachydiscus otacodensis* in Vancouver is also of importance in connection with the Indian conditions, for it increases the similarity between the Ariyalúr stage of Otacod and the Valudayur beds of Pondicherri. The fauna of the Nanaimo stage of Vancouver and the adjacent Islands was recently greatly enriched by Whiteaves,[3] and among others a Japanese species of *Pachydicus* (*Pach. haradai*, Jimbo) was recognized. I was enabled through the kindness of Mr. Whiteaves to study some very interesting new ammonites from the Straits of Georgia, which enhance the similarity between the Valudayur beds and the Nanaimo stage considerably, and I think myself justified in coming to the conclusion that the Nanaimo stage (=uppermost Chico beds of California) represents an equivalent of the Ariyalúr stage in the strict sense of the term.

In the Island of Quiriquina the cretaceous lies likewise in flat layers immediately upon the folded and denuded crystalline rocks below. These Quiriquina beds, as Steinmann calls them,[4] consist chiefly of sandy rocks rich in glauconite, which contain numerous remains of saurians and marine molluscs, and are unconformably overlain by a coarse tertiary conglomerate. Among the molluscs are nine species of ammonites, four of which Steinmann has identified

[1] K. Martin, Die Fauna der Kreideformation von Martapoera: Sammlungen des geologischen, Reichsmuseums in Leiden, Bd. IV, 5, 6, 1889.

[2] J. F. Whiteaves Geol. and Nat. Hist. Surv. of Canada, Mesozoic Fossils, Vol. II. 1879.

[3] F. Whiteaves, On some fossils from the Nanaimo group of the Vancouver cretaceous: Trans. Roy. Soc. Canada; 2nd series, I, Sect. iv, 1895, p. 119 ff.

[4] G. Steinmann, Das Alter und die Fauna der Quiriquinaschichten in Chili: Neues Jahrbuch. Beilageband X, Stuttgart 1895.

with known species of Valudayur beds, namely, *Phylloceras surya*, *Lytoceras kayei*, *L. varuna*, *Baculites vagina*. As far as one can judge from figures, the similarity is indeed very great, but I should like to draw attention to one circumstance of importance. In Pondicherri, as well as in Quiriquina, *Baculites vagina* is one of the most common fossils, but the varieties that are found in the two regions are not the same. The Chilian *Baculites vagina* is recognizable by the fact that the swellings of the ribs are a little nearer to the siphonal part of the shell than in the Indian type, for this reason the section appears to be more oval. This peculiarity may be constant, as I observed it also in the Chilian *Baculites* of this species in the British Museum, but I did not attach much value to it then as the specimens in question were not adults. Nevertheless the Chilian specimens deviate less from the typical form than the American *Baculites occidentalis*, Meek, and *B. chicoensis*, Gabb, which replace in Vancouver and California the *Baculites vagina*.

To the species which remind one of forms from Southern India belong also *Holcodiscus gemmatus*, Huppé, and *Pachydiscus quiriquinæ*, Phill, of which the former is to be compared with *H. æmilianus*, Stol., the latter with *P. otacodensis*, Stol. Of the Chilian *Hamites*, cf. *cylindraceus* Dfr., mentioned in Steinmann's work, there are at the Geological Institute of the University of Vienna plaster casts which show a perfect similarity of sculpture with the Indian *Hamites rugatus*, Forb.; unfortunately the sutures are unknown. I am not, therefore, in a position to identify them. Also a species of gastropod, *Pugnellus uncatus*, Forb., is common to this cretaceous horizon, to Southern India, and to South Africa. Relationship with the upper chalk of New Zealand (with *Plesiosauria*, *Baculites anceps*, McKay) is indicated, according to Steinmann, but it is still too incompletely examined to be discussed at present.

It is worth while to emphasize the fact that the character of the cretaceous deposits in Quiriquina in spite of their great distance from other known cretaceous regions, answers completely to what one might expect from their position in the Pacific region, and thus gives good proof of the unity of this great geographical province of animals.

V.—THE ZOOGEOGRAPHICAL CONDITIONS OF THE INDO-PACIFIC REGION.

The distribution of some species of the Indo-Pacific cretaceous province is extraordinarily wide and, owing to their close connections with the geographical conditions of that period, very interesting.

Even the most widely separated deposits of the Indo-Pacific province, namely, Natal, Vancouver, and Quiriquina show a striking resemblance to each other, and are connected not only by representative but also by some very distinctly identical species; I may mention *Lytoceras kayei* (Natal, Pondicherri, Vancouver (?), Quiriquina), *Lytoceras indra* (Natal,[1] Pondicherri, Vancouver), *Puzosia gardeni* (Natal, Ariyalūr, Vancouver). And yet the shortest line of connection between Pondicherri and Quiriquina amounts to about half the circumference of the globe and consequently the area of distribution of many forms must have been of vast extent and the most varied climatic conditions must have prevailed in it.

Pondicherri lies in about 12° N. Lat., 80° E. Long. from Greenwich; the central

[1] In a new collection at the British Museum which Mr. G. C. Crick showed to me.

European localities (with a similar cephalopod fauna) in about 40-50° N. Lat., on both sides of the meridian of Greenwich; Vancouver about 49° N. Lat., 125° W. Long. from Greenwich; Natal about 30° S. Lat., 32° E. Long. from Greenwich; Quiriquina Island about 36° S. Lat., 73° W. Long. from Greenwich. Thus two of these faunistically allied cretaceous areas belong to the north temperate zone, two to the south temperate zone, and one to the tropical zone; their position with reference to each other is such that they would fall into quite different geographical latitudes even if the poles occupied at that time positions different to their present ones.

Therefore the distribution of the ammonites depends not so much upon the climatic as upon the geographical conditions.

In a certain degree the study of the zoogeographical conditions of the modern oceans gives similar results as regards the wide distribution of Indo-Pacific species on the one hand, with the great faunistic differences between the east and west coasts of America on the other (Fischer: Manuel de Conchyliologie, Vol. I, p. 158).

It is true that at the present time the climatic differences seem to be much greater than in the cretaceous epoch, so that the distribution of species towards the north and south is in consequence rather more narrowly restricted, whilst in the senonian, for example, the Ariyalúr fauna can be well recognized not only in the tropics, but also in the two temperate zones.

But in this respect there is a great difference between the different animal groups; the ammonite fauna has generally a more universal, the gastropod and bivalve fauna a more local character, but this cannot be established as a rule without reservation. There are also among the latter classes of animals very widely distributed species (for example, *Exogyra ostracina*—Europe, India, Borneo; *Alectryonia ungulata*—Europe, Madagascar, India; *Vola quinquecostata*—Europe, Syria, Natal, India, Borneo, etc.; *Protocardium hillanum*, Sow.—Europe, Africa, India; *Pugnellus uncatus*—Natal, India, Chili, etc.), but these are proportionally more rare than among the ammonites. Moreover in the latter it is not the species that have generally such an extremely wide distribution, but a certain, more or less defined, series of representative forms. Nowhere is this better shown than in the Valudayur beds, whose ammonite fauna is distinctly related to that of the upper senonian, and yet has only two species (*Pachydiscus egertoni* and *Lytoceras kayei*), with some probability, in common therewith. One can completely agree with E. Forbes's view (Fossil Invertebrata from Southern India, p. 169) "that the marine faunas of distant localities, under similar conditions of climate, depth and sea-bottom, maintain their relations rather by representation of forms by similar forms, than by identity of species." The distribution of the ammonites is subject to the same laws as that of all other marine invertebrates, with the difference that these animals, according to the special structure of their shells, were capable of a wider distribution through the ocean currents, etc., and partly also through free locomotion. The rule, applying also to the ammonites, that a group of representative forms (Formengruppe) has a much wider distribution than a single species belonging to it (for instance, the group of *Baculites anceps*, Lam., a wider one than *Baculites anceps* itself) proves that these animals during their distribution over the surface of the ocean were liable to specific variations, and it is thus impossible that

the transportation of the empty shells[1] of a group of ammonites inhabiting a limited area should be capable of explaining the universal distribution of the fossil remains belonging to it.

An interesting fact, which has been emphasized by Steinmann,[2] is, that some Pacific types appear in the European senonian, some more rarely (*Lytoceras, Phylloceras, Hamites*), some more frequently (*Pachydiscus* and *Baculites*), and he infers from this that at that period a migration of part of the Pacific fauna into the Atlantic ocean took place on a large scale. Such a migration appears in fact to have taken place, and the Indian cretaceous lying between the Atlantic and Pacific regions is well situated to prove an exchange of the faunas.

But the question whether certain ammonite types came from the Pacific into the Atlantic or from the Atlantic into the Pacific, is not always easy to decide. For instance, certain upper senonian *Pachydiscus* and *Baculites* forms occur in the European as well as in the Indo-Pacific areas in an abundance of rather similar forms and individuals, and the stratigraphical position which they occupy (between the beds with *Nautilus danicus* and the beds of the lower senonian with *Placenticeras* and *Schloenbachia tricarinata*), is completely analogous in both areas, so that their synchronism may be assumed. For this reason every method of discovering their habitat fails us. In many groups the probability is very strong that it is the Pacific ocean [for instance, in certain *Lytoceras* (*Gaudryceras*) forms, in many *Puzosia* types (*Haueriæeras*), etc., whilst others originated, it is tolerably certain, in the Atlantic area (*Sphenodiscus, Scaphites, Turrilites*, etc.); but the question is still very difficult and can only be answered satisfactorily in special cases. Prof. Steinmann lays stress upon the fact, that the greater number of Pacific types in Europe are restricted to the western and north western parts, whilst they are absent in the southern and eastern, and he is inclined to suppose that the immigration took place from the Pacific ocean across the Arctic seas north of Asia or America. I have tried[3] to show that an exchange of faunas between the Atlantic and Pacific oceans took place in the seas south of the Indo-African continent, and that the immigration of Pacific types into Europe is clearly demonstrable in this manner. Supposing a circumpolar exchange of faunas, the most northerly deposits of upper cretaceous in the Pacific ocean ought to contain the greatest percentage of European forms; but this is not the case. The fauna of Vancouver is of purely Pacific type, as is that of Quiriquina, without any European intruders being recognizable in it, whilst such are still of great importance in the fauna of the cretaceous of Southern India, which agrees with the view that I have expressed. It becomes more and more evident that the Atlantic types decrease with tolerable constancy from west to east in the Indo-Pacific province. This is especially the case in the cenomanian and lower senonian. The series of forms of *Schloenbachia inflata*, Sow., has its habitat in the Atlantic ocean (Central Europe, West Africa, Brazil), and is distinguished there by a great abundance of species and individuals; it occurs also in India, where it is likewise well represented, and sends forth into the Pacific only quite isolated, rare forms. Similarly the group of *Acanthoceras rotomagense*, Defr., which has its chief

[1] J. Walther: Bionomie des Meeres. Jena, 1893. Bd. II., p. 508 ff.

[2] G. Steinmann: Das Alter und die Fauna der Quiriquina Schichten, p. 30.

[3] F. Kossmat: Die Bedeutung der Südindischen Kreideformation, p. 466.

distribution in the Atlantic ocean (Europe, Brazil), was recently discovered in Madagascar, along with other typical Atlantic cenomanian forms (*Turrilites*, *Baculites baculoides*), is extremely abundant in India, together with *Turrilites* and *Hamites*, but is extremely rare in the cenomanian of the true Pacific province (Yesso, California), whilst *Turrilites* are there entirely absent. We therefore find the greatest similarity with Atlantic cretaceous deposits not in the northern part of the Pacific, in the vicinity of the Polar sea, but decidedly in its western part, the Indian ocean. Species of *Schloenbachia* of the group of *Schloenbachia tricarinata*, *Placenticeras* of the group of *Pl. syrtale*, which, during the period of the lower senonian, attained such a great development in the northern part of the Atlantic ocean, on the American as well as on the European side (deposits of this age are unknown in the southern Atlantic area), came into the Indian seas (*Schloenbachia soutoni*, and *Schl. stangeri* in Natal, *Schl. dravidica* and *Placenticeras tamulicum* in Trichinopoli), but then disappear. In the Pacific ocean there is known only a quite isolated *Schloenbachia* of this group in California, and a very aberrant *Placenticeras* in Yesso. Similar conditions also obtain in the upper senonian. Whilst the similarity to corresponding deposits in Europe is not great, and recognizable Atlantic types are wanting in the fauna of Vancouver, Yesso and Quiriquina, we find in the Valudayur beds of Southern India rather a large number of species which are nearly related to European ones. We meet with, for example, *Sphenodiscus*, a genus which is elsewhere only known in the area of the Atlantic and Mediterranean cretaceous (North America, Europe, North Africa, Baluchistán), two *Scaphites* related to *Sc. constrictus*, Sow. (not yet known in the typical Pacific senonian), etc. That in this way not only did Atlantic species migrate into the Pacific region, but also Pacific species into the Atlantic, is shown by the occurrence of typical Pacific forms (*Pusosia rembda*, Forb., *Lytoceras kayei*, Forb., *Lyt. indra*, Forb.) in Natal; and these are just the very species whose related forms belong to the most important Pacific types in Europe (*Pusosia fayoli*, Gross., *Lytoceras planorbiforme*, Bohm., *L. colloti*, Gross.)

Whilst on the one hand the Indian fauna contains a mixture, of Pacific and Atlantic elements, and whilst the former increase in the cretaceous areas lying to the eastward, the latter do so to the westward (Madagascar, Natal, West Africa, etc.), and an exchange of faunas in the way pointed out, that is, round the Indo-African continent, can certainly be proved, there is as yet no solid ground for the belief that a circumpolar exchange of the faunas was effected.

The occurrence of *Baculites* on the Sosswa, east of the Ural (62·5° N. Lat.), mentioned by Professor Steinmann, may only indicate that the Central European cretaceous overlap, which extended far into Russia, penetrated to this latitude; for *Baculites* is very common throughout the upper cretaceous of Europe. But the discoveries in Greenland [1] (Niacornat, Ata, Patoot) show in their fauna very near relationship to the Fort Pierre and Fox Hills Group of the United States and thus seem to oppose the idea of a migration of Pacific forms through the Polar seas. Nevertheless the possibility is not excluded that further research in the Polar regions may furnish evidence that there also during cretaceous times the sea flowed,

[1] P. de Loriol, Om fossile Saltvansdyr fra Nord-Grönland : Meddelelser om Grönland. Vol. V. Kjöbnhavn. 1883. Part IV.

and thereby the northern parts of the Atlantic and Pacific oceans were connected together. But it may be asserted with confidence that an exchange of the faunas between the two great oceans can only be proved at the present time with perfect certainty by the deposits of Natal and Southern India, and that the phenomena recognized there are sufficient to explain the occurrence of Pacific types in Europe. Moreover it becomes more and more clear that the European faunas of the upper senonian, which are related to those of the Pacific ocean, are not only restricted to the northern and north-western parts of Europe but are also found in central and southern Europe, especially in the vicinity of the Atlantic ocean. The beds of *Pachydiscus neubergicus* are known, for instance, from the northern slopes of the Pyrenees (Stegaster limestone of Gan, with numerous ammonites, including also Pacific types), from the south side of the Pyrenees and even from N. Africa (Tunis).

This brings us to quite a peculiar and unexpected phenomenon. In the same regions of the Pyrenees, in which senonian ammonites are found, whose related forms recur in middle Europe and southern India, rich echinoderm faunas are known, which also, like the rest of the fauna, are for the greater part typically Mediterranean. This is only to be explained, I believe, by the circumstance that some ammonite types, by virtue of their great powers of distribution, penetrated from the open ocean into the otherwise faunistically very isolated Mediterranean region.

Noetling's palæontological researches[1] have proved that the echinoderm fauna of the Dunghán stage (Sphenodiscus beds) of Baluchistán is very closely related to that of the Danian of the Pyrenees, and even possesses some species in common with it, whilst it is quite different from the fauna of the Ariyalúr stage of Southern India.

This result would be quite in conformity with the fact that the echinoderm fauna of the Bágh beds (Narbada region) is in close connection with the cenomanian of the Mediterranean area of S. Europe, North Africa and Syria, but is quite different from that of the Utatúr beds which are, however, of the same age;[2] the conclusion come to with reference to the geographical distribution of land and sea is in both cases therefore the same, namely, that a Mediteranean sea stretched from Southern Europe eastward far into Asia, without being connected with the Indian Ocean.[3] Unfortunately the proofs deducible from the echinoderm fauna of Baluchistán are considerably weakened by the fact that in Southern India the echinoderms occur in the upper senonian Ariyalúr beds, whilst in the overlying faunistically very sharply separated Niniyur beds (danian) they are up to the present time wanting; it is therefore to be expected that on account of the difference in age the echinoderm fauna of the danian of Baluchistán must be different from that of the upper senonian Ariyalúr stage. It is true that the dissimilarity of the faunas seems to extend to the other animal groups, as Dr. Noetling wrote me on one occasion that the cretaceous of Baluchistán has only a few cosmopolitan species in common with that of Southern India. An early publication of the researches referring to this subject, especially on the *Ammonitidæ* (which appear not to be rare

[1] F. Noetling, Preliminary notice on the Echinoids from the upper Cretaceous system of Baluchistán: Rec. Geol. Surv. Ind., XXVII, 1894, p. 129.

[2] P. M. Duncan, On the Echinoidea of the Cretaceous Strata of the Lower Narbada Region: Quart. Journ. Geol. Soc. London, XLIII, 1887, p. 154.

[3] W. T. Blanford: Rec. Geol. Surv. Ind., XXIX., 1896, p. 53, 54.

and might indicate the existence of a lower horizon than the danian), would be very desirable. It is to be regretted that the echinoderms only of the Narbada cretaceous have been reliably worked up, whilst the rest of the fauna is known only incidentally. It depends in the first place on the exact investigation of these two cretaceous areas whether the view that the south Indian ocean was entirely excluded from the Mediterranean during the time of the upper chalk can be definitely affirmed. What is known up to the present time about the Asiatic upper cretaceous is decidedly in favour of this view.[1]

VI.—The Correlation of widely separated Fossil-bearing Deposits.

The distance of the Indo-Pacific cretaceous deposits from those of Europe with which they are compared for the purpose of determining their age is so great that the doubt is justifiable whether the similarity of the faunas allows us to establish an approximately correct comparison between them as regards the time of their deposition. Professor Steinmann leaves it an open question whether the Ariyalúr overlap occurred during the period of the lower senonian (the time of the overlap of the Gosau formation and the Aachen deposits), or, as the fauna would indicate, during the upper senonian (loc. cit., p. 31). I think that in this case the question can be decided with tolerable certainty on the evidence of the fauna. I have already mentioned that two species of the groups of *Schloenbachia subtricarinata*, d'Orb., and of *Placenticeras syrtale*, Mort., which are peculiar to the Atlantic lower senonian, and everywhere very common in it, occur in the upper Trichinopoli stage. It is therefore impossible that the upper Trichinopoli stage could be older than this division, as the two ammonite types referred to must have immigrated from there, and from this it results that the Ariyalúr overlap which begins above the horizon of these ammonites, must be younger than the lower senonian, therefore younger than the Aachen overlap.

The overlap of the lower senonian appears, according to present knowledge, to be confined to the Atlantic region, and indeed is not only found in Europe but also in the East-coast States of North America (from New Jersey to Alabama). There follows everywhere, immediately above the plant-bearing non-marine cenomanian a marine formation, which contains quite a typical lower senonian fauna: *Schloenbachia* of the group of *Schl.* (*Mortoniceras*) *texana* Röm., *Placenticeras syrtale*, Morton, *Pl. placenta*, Dekay, *Baculites asper*, Morton, etc.,

1 It is known that Neumayr (Gograph. Verbreitung der Juraformation) came to the conclusion that during the jurassic and the lower cretaceous India was connected by a land barrier with South Africa. But he was obliged on account of the jurassic discoveries in Mombassa and Madagascar, whose relations with India are unmistakable, to transfer this land connection to the extreme south, and through some recent observations it has become doubtful whether such a connection existed at all. Pavlow has shown that an *Olcostephanus* from Uitenhage beds, studied by him was scarcely to be distinguished from *Olcostephanus schenki*, Oppel, from the Spiti shales (Pavlow and Lamplugh; Argiles de Speeton et leurs equivalents. Bull. Soc. Imp. Nat. Moscou. 1892, p. 493) an observation which I am inclined to confirm from a comparison of an African specimen contained in the Geological Institute of the University of Vienna with Oppel's figures. Moreover, the relations of some Uitenhage fossils to the lower neocomian of the Salt Range, which will be worked up by Professor Waagen and myself, are very striking, and cannot easily be explained otherwise than by a oceanic connection, which probably separated India and Africa and connected the Mediterranean Sea of the lower cretaceous period with the Indian Ocean.

and is evidently equivalent to the Fort Pierre group of Dakota, whilst only in the higher beds does *Sphenodiscus lenticularis*, Owen, a typical form of the upper senonian Fox Hills group, occur.

The overlap of the European lower senonian is therefore by no means of merely local significance, though it is not observed in the Pacific ocean.

There is moreover in Europe besides the lower senonian overlap also a local overlap of the upper senonian, which, however, does not appear to be of great extent, but by reason of the faunistic relationship to the Pondicherri cretaceous is of great interest: namely, that of the Baculite chalk of Cotentin, France, which reposes immediately upon much older rocks, and as already mentioned (p. 70) possesses much similarity in its ammonite fauna to the Valudayur beds. The interest is increased through Zittel's[1] observations in the Lybian desert, where the zone of *Exogyra overwegi*, Buch., which lies immediately upon the plant-bearing Nubian sandstone, is placed in the upper senonian, on account of the general aspect of its fauna and of some identical species, and is paralleled with the so-called lower danian (Baculite-limestone of Cotentin). Moreover another overlap has been recently pointed out in Asia and its age more nearly determined, namely, that of the Cardita beaumonti beds of Baluchistán which lie immediately upon the neocomian. Their echinoderm fauna possesses, according to Noetling, a purely Mediterranean character, entirely different from that of the cretaceous of Southern India, and has many important and remarkable species in common with the danian of the Pyrenees (horizon above the Stegaster limestones). Ammonites occur there likewise (*Sphenodiscus*, further also, according to Oldham, *Baculites*, *Crioceras* ?), and it is therefore very probable that the overlap of the Cardita beaumonti beds, which is also noticeable in the Salt Range, was not very widely separated in time from the Ariyalúr overlap.

It is a truly remarkable phenomenon that the period of the upper cretaceous begins with the great overlap of the cenomanian, but that also during the lower senonian, as well as the upper senonian and the danian, the sea overflowed the land very extensively in various parts of the earth's surface. The cause of this is of course for the present as inexplicable as is the negative change of relative level, which characterizes the beginning of the tertiary era in so many places throughout the world.

The overlaps are moreover, it would seem, an excellent check upon the correctness of the calculations of the age of many deposits, and this is especially the case with reference to the cenomanian and upper senonian. The cenomanian overlap begins in Europe and in Southern India with the same zone (*Schloenbachia inflata*, Sow., *Stoliczkaia dispar*, d' Orb., *Hamites armatus*, Sow., etc.), perhaps also in West Africa (Elobi Islands and Angola) and in Brazil. As on the other hand in the Mediterranean province, where also in many places the overlapping of the cenomanian can be proved (Syria, Arabia, Narbada, etc.,) the fauna is composed chiefly of other elements, there is no doubt that overlap and the occurrence of a special fauna are in no causal connection with one another, but are quite independent phenomena. Supposing this to be the case the coincidence in time of the overlap with the appearance of a similar fauna

1 K. A. von Zittel: Beiträge zur Geologie und Palæontologie der libyschen Wüste Palæontographica, XXX, 1883, pp. 89, 93.

in a series of widely separated places in the Atlantic and the Indian oceans must be a proof of the actual synchronism of these deposits.

Also in the upper senonian the coincidence of the beginning of the overlap with the appearance of the Ariyalúr fauna in Southern India, Vancouver, and Quiriquina speaks quite decidedly for the synchronism of these deposits. That in Southern India the fauna of the overlapping Ariyalúr stage resembles so closely the fauna of the overlapping upper campanian of Cotentin permits the conclusion that these phenomena, too, are synchronous, and thus the succession of the overlaps might afford a very reliable guarantee of the correctness of the determination arrived at as to their age founded upon the fauna.

There is, however, another means of proving in some cases whether widely separated, faunistically equivalent deposits may be called merely homotaxial or truly synchronous. An example may explain this. Suppose that a place in the Atlantic province (A) has a fauna consisting of the native species a_1, a_2, a_3, ... with which the Pacific species p_2 may be associated;[1] a place in the Pacific Ocean P, on the other hand contain, besides the native fauna consisting of the species p_1, p_2, p_3......the migrated species a_3; thus the two species a_3 and p_2 would be common to both regions. If the migration occupied a geologically measurable time, it follows that if in the region A the forms a_3 and p_3 lie in the same zone, p_2 must have emigrated from a somewhat lower bed of the province P, whilst the species a_3, on account of the time necessary for the migration from A to P, can only appear in the latter place in a somewhat higher horizon, that is: the two elements of the fauna originating in different regions can only be associated in one of the two regions, in the other they must be separated. But if this is not the case, we must conclude that the lapse of time necessary for the migration must have been short, compared with the duration of a palæontological zone. The rule is simple enough; but the collection of the material necessary for proof in a special case is very difficult. Almost only such regions as lie in two widely separated, faunistically independent ocean regions, connected together by a few species, can be suitable as a starting point. Within one and the same ocean province, however large it may be, the more circumscribed habitat of certain groups of species can scarcely be determined. A comparison of the Indo-Pacific with the Atlantic cretaceous appears to me to afford some data which permit us to approach this question, but I should like to point out that in such a difficult subject where the determination of the habitat of certain animal groups forms the starting point of the conclusions to be arrived at, one must go to work with the greatest caution, and in the present state of knowledge one must be satisfied with conclusions based on probability.

Two new peculiar ammonite types begin to appear in the Valudayur beds: *Pseudophyllites indra*, Forb., and *Amm. brahma*, Forb., both of typically Pacific character. The same series of forms are also represented in the upper campanian of Europe by some rare specimens (*Pseudophyllites colloti*, Grossouvre, *Ammonites haugi*, Seunes); in the same beds appear also *Gaudryceras planorbiforme*, Bohm, doubtless a Pacific species, which I cannot distinguish from *Gaudryceras kayei*, Forb. But on the other hand the decidedly Atlantic forms *Scaphites* (*constrictus*, Sow), and *Sphenodiscus* (*ubaghsi*, Gross.), occur in the same

[1] Noetling: Records Geol. Surv. India, 1894. XXVII, p. 124 et seq.

horizon in Europe; the origin of the group of *Pachydiscus neubergicus*, Hauer, is not certain, but I should be inclined to consider it in the first place as a peculiar European group, as it seems not to be represented in the Pacific deposits of Vancouver and Quiriquina. But of the groups mentioned *Sphenodiscus siva*, *Scaphites cunliffei*, and *Pachydiscus egertoni*, Forbes (scarcely distinguishable from *P. neubergicus* Hauer), are met with in the Valudayur beds. In the Trigonoarca beds *Pachydiscus gollevillensis*, Orb., a form of the group of *P. neubergicus* which is of European origin, occurs, together with the Pacific type *Pseudophyllites*, also appearing in the same horizon in Europe. It is also of importance that the bivalves originating from the Atlantic region (*Gryphæa vesicularis*, Lam., *Exogyra ostracina*, Lam., *Alectryonia ungulata*, Schloth., *Inoceramus cripsi*, Mant.) which in their habitat everywhere characterize the upper senonian, penetrate also into the Ariyalúr group of the Indian ocean. Thus there are elements of Atlantic and Pacific faunas associated with each other, in the upper senonian of Europe and in the Valudayur and Ariyalúr beds of Southern India, and their distribution on both sides must have occupied much less time than the duration of this stratigraphical division required.

In the upper Trichinopoli beds of Varagur (Trichinopoli) *Placenticeras tamulicum*, Blanf., belonging to the Atlantic series of forms of *Plac. syrtale*, Mort., and the certainly Pacific *Gaudryceras varagurense*, Kossm., appear associated together. In a similar way *Gaudryceras mite*, Hauer (not easily distinguishable from *G. varagurense*), and *Plac. syrtale*, are connected together in the santonian of Europe.

Unfortunately we have, owing to the great distances, in the majority of cases, to deal not with identical but allied species, which must therefore be treated with great caution; in some cases, however, well defined groups of forms are in question which have only a certain small vertical distribution and therefore admit of tolerably certain conclusions about them.

An exact stratigraphy of exotic deposits, as well as a thorough investigation of their fauna might certainly supply much material for interesting observations. For the present, however, it may be sufficient to say that the phenomena accompanying the overlap, as also the study of the place of origin of certain series of forms and species, lead to the same results, namely, that the geographical distribution of a fauna does not necessitate any geologically measurable time, and that on the ground of the palæontological characters (in the first place of the ammonite faunas), one can obtain even in widely separated deposits a relatively exact determination of their age.

CONCLUSIONS.

1. The Deposits of Pondicherri fall into three palæontologically separate divisions: (1) Valudayur beds (Anisoceras beds), (2) Trigonoarca beds, (3) Nerinea beds.

2. The Valudayur and Trigonoarca beds together correspond with the lower fossiliferous Ariyalúr group of Blanford (Ariyalúr group proper); the Nerinea beds show on the one hand a similarity to this division, on the other to the uppermost beds of the Ariyalúr stage (Niniyur beds) and are probably an equivalent of the unfossiliferous sands which separate the two fossiliferous groups of beds in the Trichinopoli district.

The middle and lower divisions of the S. Indian cretaceous (Trichinopoli and Utatur stages) are not represented in the Pondicherri area.

3. The fauna of the Valudayur and Trigonoarca beds (=Ariyalúr stage, proper) corresponds with the uppermost beds of the European senonian (upper campanian Baculite-limestone of Cotentin), whilst the Nerinea beds are to be paralleled with the danian.

4. Equivalents of the Ariyalúr stage are known in Natal, Madagascar, Assam, Borneo, Yesso, Vancouver, and Quiriquina island (Chili). In the two latter places an overlap has been proved to have occurred upon much older rocks.

5. An influx of elements of the Pacific fauna into the Atlantic area during the upper cretaceous, and especially during the upper senonian, is to be recognized ; it is proved that such an exchange of faunas in the seas took place south of the Indo-African continent.

6. The study of the geographical centres of distribution of certain series of forms, as well as the coincidence of the appearance of distinct faunas with overlaps, furnish in the present case the proof that the distribution of the species did not require any geologically measurable time.

PART II. DESCRIPTION OF SPECIES.

As the list of fossils shows, the Pondicherri collection examined by me comprises only very few new species, and I can therefore, in connection with the descriptions of most specimens, refer to the monographs of E. Forbes, A. d'Orbigny and F. Stoliczka. As to the ammonites, most of them, namely, the forms belonging to the genera *Phylloceras*, *Lytoceras*, *Anisoceras*, *Ptychoceras*, *Baculites*, and *Sphenodiscus*, were revised and in part newly figured in the first part of my investigations on the cretaceous of Southern India; I can therefore restrict myself here to remarks upon the most important species of other genera (especially *Pachydiscus*). The fossil wood which in some places is abundant in the cretaceous of Pondicherri (especially horizons A and E of Warth), and in the overlying tertiary Cuddalore sandstones, is to be examined by Dr. F. R. Krasser, and the results obtained will be published later on.

PACHYDISCUS GOLLEVILLENSIS, Orb. (Pl. VI. Fig. 1, a, b, c,).

1842. *Ammonites Lewesiensis*, d'Orbigny (in part), Terrains Crétacées, Vol. I, Pl. CI. p. 336.
1850. *Ammonites Gollevillensis*, d'Orbigny, Prodrôme de Paléont., Vol. II, p. 212.
1854. *Ammonites Gollevillensis*, Sharpe, Mollusca of the Chalk, Pl. XVII, Fig. 2, p. 48.
1891. *Pachydiscus Gollevillensis*, Seunes, Ammonites du calcaire à Baculites du Cotentin : Mém. Soc. Géol. France, Paléontologie, Vol. II, 1891, No. 2, Pl. V., Figs., 1-3, p. 10.
1893. *Pachydiscus Gollevillensis*, Grossouvre, Ammonites de la Craie supérieure, Mém. Carte Géol. de la France, Pl. XXIX, Fig. 4, Pl. XXXI. Fig. 9, p. 214.

The only example of *Pachydiscus* which has been found up to the present in the Trigonoarca beds shows the following characters:—The whorls have a high mouth, a rather narrow periphery, rounded at the edges, almost imperceptibly flattened in the median line, and high, very slightly curved sides, which flow inwards to form a low but distinct steep umbilical wall. The involution amounts to more than half of the preceding whorl, but its exact measurement

cannot be given as the inner whorls of the shell are evidently somewhat crushed. At the edge of the umbilical wall there are 9 to 10 tubercles from each of which proceeds an obscure radial rib, which disappears on the sides, so that its connection with the short, strong ribs on the periphery cannot be perceived. The outer ribs, of which I counted 24 on the last half of the outer whorl (all composed of air chambers), are very decidedly weakened in the narrow siphonal region, but somewhat thickened on either side; they only reach the outer part of the sides, and here they soon fade off. The suture-line is somewhat abraded, but is nevertheless very characteristic. The external lobe is much shorter than the first lateral lobe, the external saddle symmetrically twofold, and its base on each side much narrowed by deep cut indentations. From the deep, distinctly threefold, first lateral lobe arises perceptibly the basal limitation, as the second lateral and the first auxiliary lobe are becoming shorter than the preceding one. The first lateral saddle is about the same height as the external saddle and likewise twofold, the second lateral saddle is much smaller and not symmetrically shaped, the first auxiliary saddle is again somewhat larger and wider, and is divided into two parts by an indentation which cuts just into the umbilical margin; to this indentation a few small ones are attached, which rapidly incline towards the suture, thus forming a small sutural lobe.

In all the characters above mentioned the Indian specimen agrees perfectly with the examples of *Pachydiscus gollevillensis* from the Baculite limestone of Cotentin (Dep. Manche), which are beautifully figured by Seunes and Grossouvre; the example figured by Seunes, Pl. V, fig. 2, shows an especially striking resemblance. The number of the short peripheral ribs, thickened on both sides of the siphonal line (25 in an arc equal to the last half whorl of the example here described) is almost exactly the same, likewise the number and shape of the umbilical tubercles, which in the French examples also fade away without any visible connection with the outer ribs. As to the suture line, a glance at Pl. XXX, fig. 2, in Grossouvre's monograph (the photographic reproduction of a cast with well preserved septa) shows that not the least deviation exists. In the French specimens also the lobes lean towards the umbilical suture; the first auxiliary saddle is divided near the margin of the umbilicus by an indentation, the little suspensory lobe is distinctly visible; the external lobe is smaller than the first lateral lobe.

One can therefore, without any hesitation, ascribe the example described from the Trigonoarca beds to this characteristic species of the upper campanian (upper mucronata beds, Maëstrichtien).

It is further closely connected with *Pachydiscus crishna*, Forb., and *P. egertoni*, Forb., from the Valudayur beds. The latter has in common with it a section indicating a high mouth, short, strong ribs on the periphery (likewise somewhat thickened on each side of the siphonal line), and isolated umbilical tubercles; the suture line also is very similar. The difference is only shown by the fact that *Pach. crishna* increases more slowly, is less involute, and consequently possesses, a more open umbilicus.

Pachydiscus egertoni is distinguished from the two above mentioned forms by a wider, less high section, and therefore a more contracted suture line. Otherwise *Pach. egertoni* shows nearly in every respect the same characters as the European *Pach. neubergicus*, Hauer, a typical form of the upper campanian, and I should be embarrassed if I had to indicate marked differences between the two species.

a

I intend to reserve a minute investigation into the relationship of these species for the second part of my monograph on the ammonites of the South Indian cretaceous, and hope that meanwhile I shall have an opportunity of comparing Forbes's examples of *Pachydiscus egertoni* with those of the European species *P. neubergicus.*

The little species *Pachydiscus ganesa,* Forbes,=*P. soma,* Forbes. (see Pl. VI, fig. 2 *a-c*) is also very closely related to *P. egertoni,* and it is quite possible that it represents only an immature form of the latter. The young stage of growth of *P. neubergicus* possesses also quite an entraorditary resemblance with *P. ganesa,* as a comparison of the figured specimen in this work with Pl. XXVI, Fig. 3, in Grossouvre's Monograph shows.

It can now be affirmed with certainty that the four Indian species: *Pachydiscus egertoni, P. ganesa, P. crishna, P. gollevillensis,* represent a perfect equivalent of the European group of forms of *Pachydiscus neubergicus,* and have at least one species (*P. gollevillensis*) in common with it.

The fifth Indian species of *Pachydiscus, P. menu,* Forbes, belongs to quite another group of forms and is in the middle stage of growth exceedingly like *P. ariyalurensis,* Stol., but acquires a very peculiar second row of tubercles on the body chamber. It seems to me of importance that there is an undescribed species associated with *Pachydiscus neubergicus,* from Neuberg (Steiermark), which shows quite similar features of form and sculpture to those of *P. menu.* (The only specimen known to me is in the Geological Institute of the University of Vienna.)

Stoliczka has also described and figured (Pl. LII, Fig. 3), *Pach. menu,* from the Trichinopoli group of Anapadi, but an examination of the example mentioned proved that this identification could not be sustained.

Locality, ½ mile west of Rautankupam, Trigonoarca beds.

PACHYDISCUS *sp. cf.* GOLLEVILLENSIS, Orb. Pl. VI, Fig. 3, *a, b, c.*

Among the few species of ammonites which the Valudayur beds, once so rich in this group of animals, have furnished to this new collection, is a fragment, which must be referred to the genus *Pachydiscus,* but in consequence of its small size does not admit of all the characters necessary for the recognition of a species of this group, so rich in forms, being ascertained. The whorls increase very slowly and the involution amounts to about three fifths of their height. At a diameter of about 5 cm. the section is almost perfectly circular, a little wider than high; afterwards the sides become flattened and gradually merge into the rather narrow, rounded periphery, whilst their boundary at the umbilical wall is somewhat more distinctly marked. At the edge of the umbilicus there are rounded tubercles (on the figured fragment three in number), whilst elsewhere no trace of sculpture is to be seen.

The suture line agrees with that of *Pachydiscus neubergicus,* Hauer, and *P. gollevillensis,* shows exactly the same details of indentation, of the proportions in size of the individual lobes and saddles, as well as the inclination of the lobes towards the umbilical suture. The first auxiliary saddle is on the umbilical edge as in *P. gollevillensis.* On the whole the specimen described is pretty near to this species and is only distinguished from it by the want of ribs and by the slower growth. But as the young forms of the Pachydiscus belonging to this group are

smooth (for example, in *Pachydiscus neubergicus*), and the mode of growth of *P. gollevillensis* in its young stage is not known, one cannot decide without further information whether the present specimen belongs to a distinct species or not.

Locality, ½ mile north of Tutipet, Valudayur beds.

DESMOCERAS DIPHYLLOIDE, Forbes, sp.

1846. *Amm. diphylloides*, Forbes, Trans. Geol. Soc., London, 2nd Ser., Vol. VII, p. 105, Pl. VIII, fig. 8.

1865. *Amm. diphylloides*, Stoliczka, Cret. S. Ind., Vol. I, p. 119.

Of this species there are in the collection of the Geological Society several very well preserved examples showing deep, S shaped constrictions, which Forbes does not mention in his description. I have before me in the new collection only a fragment of a large-chambered example (diameter about 7 cm.), which agrees very well with the specimens of the original collection, and which I shall figure later on in connection with them.

The section is somewhat higher than wide, the sides flattened merging gradually into the rounded periphery on the one hand, and into the umbilical wall on the other. The constrictions marking the cast are curved in an S-shaped manner, and project tongue-like on the periphery.

The suture line shows all the characters of a *Desmoceras* of the group of *D. latidorsatun*, Mich.

The examples which Stoliczka figures from the Utatur group as *Amm. diphylloides* show a somewhat more rounded section (Pl. LIX, Figs. 10, 12); the constrictions show a shorter, broader tongue on the periphery. From the Ariyalúr stage of Otacod and Karapadi there are some specimens, which agree well in form, sculpture and suture line with the Valudayur form. Very nearly related also is *Desmoceras pyrenaicum*, Gross.[1] from the French santonian (middle senonian) and *Amm. selwynianus*, Whiteaves,[2] from the Nanaimo stage of Vancouver, of which Mr. Whiteaves sent me a very beautiful example for comparison.

The second species of *Desmoceras* from the Valudayur beds, *D. yama*, Forbes, is insufficient for any comparison with forms from other cretaceous regions.

Locality, ½ mile north-west of Rautankupam, Valudayur beds.

AMM. (*n. g. aff.* HOLCODISCUS) BRAHMA, Forbes.

1846. *Amm. brahma*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, p. 100, pl. VIII. Fig. 1.

1865. *Amm. brahma*, Stoliczka, Cret. S. India, Vol. I, p. 163, Pl. LXXIX, Figs. 2-4.

Of this species, which, in the Pondicherri district, has only been found up to the present time in the Valudayur beds, though occurring pretty frequently in them, there lies before me a single fragment, not well preserved, but easily recognizable, from the Trigonoarca beds of Saidarampet. Several beautiful examples of the same species are in Dr. Warth's collection, from the Trichinopoli district. These come from the Ariyalúr beds of the vicinity of Otacod, from whence also Stoliczka mentions a specimen. This remarkable type is represented in France by a

[1] A. de Grossouvre, Les Ammonites de la Craie supérieure. Paris, 1893, Pl. XXXVII, Fig. 9, *a*, *b*, *c*.

[2] J. F. Whiteaves, Geol. Nat. Hist. Surv. Canada, Mesozoic Fossils, Vol. I, Pl. II. Montreal, 1879. Pl. XIII, Fig. 1.

very closely related species, *Am. haugi*, Seunes (called by Seunes[1] *Pusosia*), regarded by Grossouvre[2] as a stage of growth of *Lytoceras planorbiforme*, Böhm., which occurs in the upper campanian (uppermost senonian) of the Department of the Basses Pyrenées.

A description of the generic features of *Am. brahma* and the allied species *Amm. vishnu*, Forbes, and *Am. haugi*, Seunes, will be published in the second part of the researches into the cretaceous fauna of Southern India. But it may be remarked here that this group has nothing to do with *Lytoceras*, with which it has been united by Neumayr (Classification der Kreideammonites) and by Zittel (Handbuch der Palæontologie, Vol. II. genus Lytoceras), but is nearly related to *Holcodiscus* and *Pachydiscus*.

Locality: Pondicherri, Valudayur beds and Trigonoarca beds (Saidarampet).

NAUTILUS (HERCOGLOSSA) TAMULICUS, n. sp. Pl. VI, Figs. 5, 6; Pl. VII, Fig. 1.

This species, of which I have two fragmentary examples before me, possesses strongly involute whorls, sagittate in section, which surround a very small umbilicus. The sides are without ornaments and moderately inflated, steeply inclined towards the umbilicus, near which they are widest; they converge regularly towards the periphery, which is somewhat rounded in the young, pointed in the old, shell. The septa are numerous, project towards the periphery, forming a sharp angle, and describing on the sides a deep, backwardly directed sinus, which is separated from the suture by a regularly rounded saddle. The siphuncle is situated very near the inner side, its projection would meet the turn of the curve, which the suture line describes in its transition from the side lobe to the saddle.

A related species, not yet described, occurs in the Ariyalúr beds of Kalmodu, near Otacod, but this possesses a narrower section, the keel is separated from the sides by a slight groove and is divided in the adult, so that it develops a furrow in the siphonal region.

Nautilus leiotropis, Schlüter,[3] from the Emscher marl of Northern Germany, is more inflated and possesses less deeply sinuated septa.

Locality. Saidarampet, Kadaperikupam ?, Nerinea beds.

The other *Nautili* belong to species which have all been described by Forbes and Blanford. There is a very fine, large specimen of *N. serpentinus*, Blanford, from the Orbitoides-bearing Nerinea limestone of Saidarampet, whilst *Nautilus danicus*, Schl., related to it, is not represented in Dr. Warth's collection. Of the species which Blanford identified with *Nautilus clementinus*, Orb. (gault), there are several badly preserved examples which agree with those of the Trichinopoli district, but are insufficient for purposes of description. But it must be pointed out that the species from both districts differ from the European species and must receive a new name.

[1] J. Seunes: Mém. Soc. Geol. de France, Paléontologie, Vol. II, No. 2, p. 20, Pl. VI, Fig. 1.

[2] A. de Grossouvre: Ammonites de la Craie supérieure, p. 531, Pl. XXXIV, Figs. 4, 5; Pl. XXXV, Fig. 7.

BELEMNITES, sp. ind. Pl. VI., Fig. 7, *a*, *b*.

1846. *Belemnites* (?) *fibula*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, 119, Pl. IX, Fig. 3.

From the sands of the Trigonoarca beds I have a single, rather eroded fragment of a belemnite,[1] which agrees with the species described by Forbes as *B. fibula*. In the phosphatic beds of the Utatur stage of Utatur, Trichinopoli district, numerous very well preserved belemnites are found, which H. F. Blanford was inclined to identify with the Pondicherri species on the ground of E. Forbes's sketch (Cret. Fauna of S. India, Vol. I., Cephalopoda, p. 3). But the section of the latter has the form of a rectangle with rounded edges, the alveolar cavity is rather long and narrow, the wall of the rostrum not smaller on the sides than in the ventral and dorsal regions. In the belemnites described from the Utatur group the section of the wall and the alveolus is oval, the latter is moreover excentric and the wall on the ventral side of the rostrum somewhat thicker. The Utatur species must therefore have a new name, whilst the specific name *fibula* had better be abandoned, as the examples known up to the present time are not sufficient for a specific diagnosis.

Locality, ½ mile N. N. W. of Rautankupam, Trigonoarca beds.

PUGNELLUS UNCATUS, Forbes. Pl. VI, Fig. 8.

1846. *Strombus uncatus*, Forbes, Trans. Geological Society, London, 2nd ser., VII, p. 129, Pl. XIII, Fig. 16.

1847. *Strombus semicostatus*, d'Orbigny, Voyage de l'Astrolabe. Paléont. Pl. II, Fig. 38.

1867. *Pugnellus uncatus*, Stoliczka, Cret. S. India, Vol. II, p. 22, Pl. III, Figs. 9—13.

1887. *Pugnellus uncatus*, Philippi, Die tertiären und quartären, Versteinerungen Chiles. Leipzig.

This species passes up from the Valudayur beds, in which it is very common, into the Trigonoarca beds, from whence I have a well preserved cast agreeing perfectly with the typical examples, from which the shell has been broken off. *Pugnellus* is a genus which belongs in the first place to the Indo-Pacific region and is represented in the upper cretaceous of Southern India by three species (*P. uncatus*, Forb., *P. contortus*, Sow., *P. granuliferus*, Stol.); it further occurs in Natal[2] (*P. uncatus*), in Borneo,[3] (*Pugnellus sp.*, Martin), in California[4] (*P. manubriatus*, Gabb, and *P. hamulus*, Gabb) and in Chili,[5] (*P. uncatus*, *P. tumidus*, Gabb); but it is also known in the Colorado group of the Rocky Mountains

[1] Cl. Schlüter, Cephalopoden der oberen deutschen Kreide, I: Palæontographica, XXIV, Pl. XLVIII, Figs. 1, 2.

[2] C. L. Griesbach, Geology of Natal: Quart. Journ. Geol. Soc. London, XXVII, 1871, p. 61.

[3] K. Martin, Die Fauna der Kreideformation von Martapoera: Sammlungen des geologischen Reichsmuseums in Leiden, IV, Nos. 5, 6, 1889, p. 188, Pl. XX, Figs. 10-12.

[4] W. M. Gabb, Palæontology of California, Vol. I, pp. 124, 125, Pl. XVIII, Fig. 48; Pl. XX, Fig. 81; Pl. XXIX, Fig. 229.

[5] Steinmann, Quiriquinaschichten: Neues Jahrb., Beilage Bd. X, 1, p. 96, Pl. VII, Figs. 15, 16.

region of the United States,[1] (Pugnellus sandstone), and in the Mississippi cretaceous (one species in each).

Locality, Pondicherri district, Valudayur beds, Trigonoarca beds.

GOSAVIA INDICA, Stoliczka. Pl. VII, Fig. 3, *a*, *b*.

1867. *Gosavia Indica*, Stoliczka, Cret. S. Ind., Vol. II, p. 73, Pl. VI, Figs. 3, 7, 8.

The specimens from Pondicherri agree very well with Stoliczka's figures and descriptions, but the spire appears to be a little lower than in the examples from the Trichinopoli district, which all come from the zones lying between the Trichinopoli and Ariyalúr stage. The largest of the Pondicherri examples (a fragment from Rayapudupakam) shows the numerous folds on the inner lip very well.

Locality, ½ mile N. N. E. of Rautankupam, Valudayur beds; Rayapudupakam, Trigonoarca beds.

VOLUTILITHES MURICATA, Forbes. Pl. VII, Fig. 2.

1846. *Voluta muricata*, Forbes, Trans. Geological Society, London, 2nd ser., VII, p. 131, Pl. XII, Fig. 4.

1867. *Volutilithes muricata*, Stoliczka, Cret. S. India, Vol. II, p. 94, Pl. IX, Fig. 5.

I have figured this species again as the specimen figured by Forbes, and also that by Stoliczka, is only fragmentary; but to the description which the latter has given there is nothing to add.

Locality, ½ mile north of Tutipet, Valudayur beds; ¼ mile west of Rautankupam, Trigonoarca beds.

HINDSIA EXIMIA, Stoliczka.

1867. *Hindsia eximia*, Stoliczka, Cret. S. India, Vol. II, p. 135, Pl. XI, Figs. 15—17.

In the Kaye and Cunliffe collection in the Museum of the Geological Society of London there is a specimen which completely agrees with this species, but has been confounded with *Pollia pondicherrensis*, Forb., and has therefore not been described.

Locality, Pondicherri district, lumachelle of the Valudayur beds.

TRICHOTROPIS *sp. cf.* KONINCKII, Müller. Pl. VIII, Fig. 2, *a*, *b*.

From the Trigonoarca beds of Tutipet there are in the collection two phosphatized casts, retaining the sculpture of the shell, which belong to the genus Trichotropis, and are related to *Trich. koninckii* as well as to some other forms from the Trichinopoli district. The larger of the two specimens shows only three whorls which have two spiral ridges, the stronger of which is situated in the middle between the anterior and posterior sutures, whilst the weaker anterior one disappears under the suture and is only seen on the last whorl. Two spiral ribs are visible, one between the two ridges, another on the convex base of the last whorl. Longitudinal ribs which were probably very strong on the shell are likewise pretty distinctly marked on the cast; they form tubercles on the posterior ridge, and proceed from thence

[1] T. W. Stanton, The Colorado Formation: Bull. United States Geological Survey, No. 106, Washington, 1893, p 148, Pl. XXXI, Figs. 7—11.

as flat prominences to the posterior suture. The aperture is oval, somewhat contracted anteriorly and posteriorly. This species is distinguished from *Trichotropis koninckii*[1] of the Achen greensand by the smaller size of the last whorl, by the shorter distance of the posterior ridge from the suture, and by the presence of spiral ribs. Holzapfel has pointed out that Stoliczka's examples[2] from the Trichinopoli group are different from the European species; moreover, Stoliczka has united two Indian species under the name of *Trichotropis koninckii*, to one of which (Stol., loc. cit., Pl. XIII, Fig. 7) the present specimens from Pondicherri are very similar; perhaps they should even be united with them, unless the presence of the two spiral ribs forms a special feature of the latter.

Locality, ½ mile W. S. W. of Tutipet, Trigonoarca beds.

NERINEA, n. sp. (BLANFORDIANA, Stol.?). Pl. VII, Fig. 7; Pl. VIII, Fig. 1.

In the hard, sandy Orbitoídes limestone, which overlays the Trigonoarca beds in several places, for instance at Valudayur and Saidarampet, there are found casts of large Nerineas which seem to form a special peculiarity of this horizon, for which reason I have bestowed upon it the designation Nerinea beds. But I abstain from giving a specific name, as nothing of the sculpture is to be seen, and therefore an exact comparison with described species is out of the question.

The shell is conical, not very slender, with numerous low whorls which have slightly concave sides on the cast. The base is flat and low and meets the sides in a distinct edge. The aperture is widely quadrate; two columella folds, somewhat deeply indented, are present; every whorl joins the upper part of the contiguous one with a projecting spiral rib, so that the section of each whorl, besides the two columella folds, shows a groove in the middle of the upper part and a projecting rib in the middle of the under.

There seems to be a relationship between this species and *Nerinea blanfordiana*, Stol.,[3] but the want of the sculpture does not permit of any sure determination. Unfortunately Stoliczka does not figure a section of a whorl showing the folds.

As already mentioned in the geological part of this memoir, *Nerinea* occurs in the Niniyur beds (danian) of the Trichinopoli district (H. F. Blanford: Mem. Geological Survey of India, IV, p. 141), and are also several times mentioned by Stoliczka as associated with various forms of gastropods described by him; on pages 221 and 227 he even directly refers to *Nerinea blanfordiana* in the Niniyur group, whilst in the description of this species he mentions only localities from the Utatur group. An examination of the specimens in the Museum of the Geological Survey could alone elucidate this question.

The species here described differs considerably from other cretaceous Nerineas known to me.

Locality, S. S. E. of Valudayur, Nerinea beds.

CERITHIUM KARASURENSE, n. sp. Pl. VII, Figs. 5, *a*, *b*; 6, *a*, *b*.

The shell of this species is very slender, with numerous, fairly high whorls,

[1] E. Holzapfel, Die Mollusken der Aachener Kreide: Palæontographica, XXXIV, Pl. XV, Figs. 6—9, p. 149.
[2] F. Stoliczka, Cret. S. India, Vol. II, p. 158, Pl. XIII, Figs. 7—9.
[3] F. Stoliczka, Cret. S. India, Vol. II, p. 184, Pl. XIV, Figs. 4—6.

which are scarcely at all inflated and only very slightly indented at the suture. Just below the posterior suture there is a raised rim upon which numerous rounded tubercles are seen (seventeen on the last whorl). An anterior row of tubercles, which indicates the ridge between the somewhat inflated under part and the sides, is covered by the suture and consequently is visible only on the last whorl. They are more numerous than the posterior tubercles and form the starting point for the curved longitudinal ribs, which, on the one hand pass over the sides of the whorl and can partly be traced as far as the posterior row of tubercles; on the other hand they converge towards the lower end of the aperture, getting at the same time gradually fainter. There is no spiral sculpture. The aperture is somewhat narrowed anteriorly and posteriorly; the interior end of the shell is broken off, and therefore nothing of a canal is to be seen.

In the *Orbitoides* bearing Nerinea beds of Saidarampet there occur pretty large examples of *Cerithium*, which very probably are to be identified with the species here described. The best preserved figured specimen shows, in the form of the whorls and in the sharply conical shape of the shell, a complete agreement with the example from Karasur, and possesses also a swollen ridge with rounded tubercles at the posterior suture. All other traces of sculpture are removed by weathering, but it seems as if the row of tubercles on the ridge between the sides and the base of the shell had also been there. A second example shows in section two faint columella folds. In this feature as well as in the form of the shell there is decidedly a near relationship to *Cerithium inauguratum*, Stol.,[1] but the latter may be distinguished by the presence of several spiral rows of fine tubercles as well as by the absence of the longitudinal ribs, and an anterior row of tubercles.

There is moreover in the collection worked up by Forbes also *Cerithium inauguratum*, Stol. (already thus determined by Stoliczka in his examination of the collection, but not mentioned in his publications). Another species occurring abundantly in the Ariyalúr stage—*Cerithium arcotense*, Stol. (loc. cit., p. 197, Pl. XV. Figs. 2-5)—is represented in the same collection from Pondicherri (lumachelle of the Valudayur beds).

Locality of *Cerithium karasurense*, Karasur, Trigonoarca beds; Saidarampet, Nerinea beds.

TURRITELLA WARTHI, n. sp. Pl. VIII., Fig. 3, *a*, *b*.

A very slender form with regularly convex whorls, which are separated from each other by a somewhat deeply indented suture, and are distinguished by a very, fine, regular, spiral sculpture. Three of the spiral lines in the middle of the whorl are more distinct.

Related to this species is *Turritella ventricosa*, Forbes (loc. cit., p. 123, Pl. XIII, Fig. 3), which, however, increases considerably quicker, and has a somewhat coarser sculpture; the species from Niniyur, which Stoliczka has identified with *Turr. ventricosa*, differs greatly.

Very similar to this species is *Turritella quadricincta*, Goldfuss, from the German senonian (E. Holzapfel: Palæontographica, XXXIV, Taf. XV, Fig. 16.); but it has four instead of three coarser spiral lines. *Turritella meadii*, Baily, from

[1] F. Stoliczka, Cret. S. Ind., Vol. II, p. 193, Pl. XV, Figs. 15, 19, 20.

Natal (Quart. Journ. Geol. Soc., London, 1855, p. 458, Pl. XII, Fig. 6), shows stronger longitudinal lines and more numerous spiral ribs.

Locality, ½ mile north and 1 mile N. N. W. of Tutipet, Valudayur beds.

TROCHUS ARCOTENSIS, Forbes. Pl. VIII, Fig. 4, *a*, *b*, *c*.

1846. *Trochus Arcotensis*, Trans. Geol. Soc., London, 2nd ser., VII, p. 119; Pl. XIII, Fig. 9.

The specimens of *Tr. arcotensis* from Pondicherri which I have before me (Forbes's specimens come also from there) differ from the highly ornamented *Tr. geinitzianus*, from the Bohemian cretaceous, with which Stoliczka united it, as well as from the examples identified with them from the Trichinopoli district. The spiral sculpture is very faint, the outer ridge of the whorls without tubercles and not sharp; that part of the shell between it and the suture is inflated, not simply roof-like, as in Stoliczka's examples, which indeed come very near to *Tr. geinitzianus* (loc. cit., Vol. II, Pl. XXIV, Figs. 11—15.)

Very nearly related to *Trochus arcotensis* is a species from Natal, which Baily has named *Solarium pulchellum* (Quart. Journ. Geol. Soc., London, 1855, p. 458, Pl. XII, Fig. 3), but the height of the spire is somewhat less. In the lumachelle of the Trichinopoli stage of Garudamangalam two species of *Trochus*, not yet described, occur, of which one is very similar to *Tr. arcotensis*, but has a sharp outer ridge, and the upper part of the whorl is not inflated, but roof-like.

Locality, ½ mile N. W. and north of Tutipet, etc., Valudayur beds.

TEINOSTOMA CRETACEUM, d'Orbigny. Pl. VIII, Fig. 5, *a*, *b*, *c*.

1867. *Teinostoma cretaceum* (d'Orbigny) Stoliczka, Cret. S. Ind., Vol. II, p. 350, Pl. XXV, Fig. 7.

The extremely small species described by d'Orbigny from Pondicherri, and figured by Stoliczka from the Ariyalúr stage of Comarapalaiam, is very common and always beautifully preserved in the lumachelle of the Valudayur beds, so that the brownish, radiating colour bands are often to be seen on the shiny, porcelelanous shell.

Locality, ½ mile north of Tutipet, Valudayur beds.

BULLINA CRETACEA, d'Orbigny. Pl. VIII, Fig. 6, *a*, *b*.

1847. *Bulla cretacea*, d'Orbigny, Voyage de l'Astrolabe. Paléontologie, Pl. III, Figs. 18—21.
1867. *Bullina cretacea*, Stoliczka, Cret. S. Ind., Vol. II, p. 414 (non Pl. XXVII, Fig. 19).

Small examples of *Bullina* are among the most common fossils in the Valudayur beds, and particularly one species which d'Orbigny describes as *B. cretacea*. A special feature of this form is the striking thickening of the lines of growth at the upper end of the cylindrical shell which there develop into slight folds. In the examples from Garudamangalam, which Stolizcka figured as *B. cretacea*, this feature is not present, moreover they are more distinctly spirally striated and attain a somewhat larger size.

Besides *Bullina cretacea* there occurs in Pondicherri another species, Pl. VIII, Fig. 7, *a*, *b*, ornamented with fine, spiral lines, which does not show the posterior thickening of the lines of growth, is very slender, but has not a cylindrical shape; it

is considerably narrowed posteriorly, whilst the sides are slightly inflated. This form might be perhaps identical with the slender variety of *Bullina alternata*, Forb., which Stoliczka (loc. cit., Pl. XXVII, Fig. 18) figures from the upper Trichinopoli stage of Varagur.

Locality, N. N. W. of Tutipet, ½ mile north of Tutipet, etc., Valudayur beds.

EUPTYCHA LARVATA, Stoliczka. Pl. VII, Fig. 4, *a*, *b*.

1867. *Euptycha larvata*, Stoliczka, Cret. S. Ind., Vol. II, p. 426, Pl. XXVI, Fig. 6.

The two phosphatized examples from Pondicherri agree entirely with Stoliczka's type specimen from Comarapalaiam.

Locality, Rayapudupakam, Trigonoarca beds.

DENTALIUM CRASSULUM, Stoliczka. Pl. VIII, Fig. 8, *a*, *b*.

1867. *Dentalium crassulum*, Stoliczka, Cret. S. Ind., Vol. II, p. 444, Pl. XXVII, Fig. 21.

This species was described by Stoliczka from the upper Trichinopoli stage of Serdamangalam, but I have it also from the lumachelle of the lower Trichinopoli stage of Garudamangalam; also from the white sands of the Ariyalúr stage of Karapadi, and one example with completely similar features from the Valudayur beds of Pondicherri.

Dentalium arcotinum, Forb., also frequently occurring in Pondicherri, is common to the Trichinopoli and Ariyalúr groups, as numerous examples from Garudamangalam are present, which I cannot distinguish from the Pondicherri ones.

Locality, 1 mile N. N. W. of Tutipet, Valudayur beds.

PHOLADOMYA LUCERNA, Forbes. Pl. VIII, Figs. 9, 10, *a*, *b*.

1846. *Cardium lucerna*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, Pl. XVII, Fig. 10.

1871. *Pholadomya caudata*, Stoliczka (non Römer), Cret. S. Ind., Vol. III.

This species is distinguished from *Pholadomya caudata*, Römer (Verstein. des norddeutschen Kreidegebirges, Hannover, 1841, p. 76, Taf. X, Fig. 8), by the less strongly curved lower margin, and the almost equally rounded anterior and posterior sides, of which the latter is not so strikingly narrowed as in the examples from the German senonian.

Locality, Pondicherri district, Pulichapalaiam, Tutipet, Rautankupam, Horizon B and C.=Valudayur beds; Tutipet, Rautankupam, Trichinopoli district, Trigonoarca beds of Parcheiri and Serdamangalam, upper Trichinopoli stage (rep. lower Ariyalúr stage).

CORBULA PARSURA, Stoliczka. Pl. IX, Fig. 11, *a*, *b*.

1871. *Corbula parsura*, Stoliczka, Cret. S. Ind., Vol. III, p. 44, Pl. I, Figs. 23, 24; Pl. XVI, Figs. 3, 4.

1893. *Corbula parsura*, F. Kossmat, Einige Kreideversteinerungen vom Gabun (Sitzber. d. k. Akad. d. Wiss., Wien, 1893), p. 579, Taf. I, Fig. 3, *a*, *b*, *c*.

Of this easily recognized species there was found in the Valudayur beds a small example, about 3 mm. long, which agrees with the described type specimens from the lumachelle of Garudamungalam (Trichinopoli stage), as well as with the figured specimen from the upper cretaceous of Gabun (West Africa) in the pecu-

liarly thick form of the shell and the strong concentric folds. The circumstance is of special importance that this species, the only one from the upper cretaceous of the Gabun, which is to be identified with one already described, passes up into the upper senonian in India, for I was formerly already of opinion that the fauna of the calcareous marl of the Gabun according to its general habit (*cf.* for example *Echinobrissus atlanticus*, Koss.) belongs rather to the senonian than to the turonian, a determination of age, which thus now no longer contradicts the fact of the occurrence of *Corbula parsura.*

Locality, ½ mile north of Tutipet, Valudayur beds.

TELLINA PONDICHERRENSIS, Forbes. Pl. IV, Figs. 13, 14, *a*, *b*.

1846. *Tellina? pondicherrensis*, Forbes, Trans. Geol. Soc., London, 2nd Ser., VII, p. 142, Pl. XVIII, Fig. 15.

Non 1871. *Baroda (Icanotia) pondicherrensis*, Stoliczka, Cret. S. Ind., Vol. III, p. 167, Pl. IV, Fig. 5; Pl. XVII, Fig. 4.

Of this species, which was described by Forbes as *Tellina?*, but belongs certainly to this genus, I have before me several rather well preserved examples, which are all distinguished by the somewhat long, narrow shape of the shell, similarly rounded anterior and posterior margins, as well as the almost straight lower margin. The umbones are pointed, placed far forward towards the anterior end: the shell is thin and provided with only fine lines of growth. *Baroda pondicherrensis*, Stol., from the Utatur stage, which was identified with this species, has a thicker shell, stronger lines of growth, and further shows fine lines radiating from the umbones.

Locality, ½ mile north of Tutipet, Valudayur beds.

TELLINA (ARCOPAGIA) FORBESIANA, n. sp. Pl. IX, Fig. 12, *a*, *b*, *c*.

The figured left valve of this species, very slightly inflated, has a somewhat long form, a narrow anterior, and a broad posterior side, with the umbo placed in the middle. The posterior part of the shell flattens towards the broad, rounded posterior margin, and shows extremely fine striation, radiating from the umbo and producing quite a delicate network of thin lines of growth, which disappear before they reach the margin. The dentition is unknown. In the related species, *Arcopagia gabunensis*, Kossmat[1] from the upper cretaceous of the Gabun, the shell is posteriorly about the same width as anteriorly, the concentric sculpture consists of raised lines, closely and regularly placed together, the radiating striæ near the posterior margin are more perceptible. *Tellina monilifera*, Gabb,[2] from the Martinez group of California is more inflated and has a rather strongly curved lower margin as well as a narrow, rounded posterior margin. Among the Indian species there is none which would require a close comparison with the described species.

Locality, 1 mile N. N. W. of Tutipet, Valudayur beds.

[1] F. Kossmat, Sitzungsberichte d. k. Akad. d. Wiss, Wien, 1893, p. 580, Taf. I, Fig. 7, *a*, *b*.
[2] Palæontology of California, Vol. I, p. 157, Pl. XXII, Fig. 134.

TRIGONOARCA GALDRINA, d'Orbigny. Pl. IX, Figs. 1—3.

1847. *Arca galdrina*, d'Orbigny, Voyage de l'Astrolabe et de la Zélée. Paleontologie, Pl. V, Figs. 32, 33.

1871. *Trigonoarca galdrina*, Stoliczka, Cret. S. Ind., Vol. III, p. 355, Pl. XVIII, Figs. 2-5.

As this species, which occurs in numerous examples in the middle horizons of the cretaceous of Pondicherri, but also begins to appear isolated in the Valudayur beds, is only mentioned by Stoliczka from the Ariyalúr stage of Serdamangalam and Sripermatúr, outside this district, whilst examples from Pondicherri are figured only in d'Orbigny's rare book, I show a few figures of well preserved examples on Plate IX. There is nothing to add to Stoliczka's description. In the related species *Trigonoarca gamana*, Forbes, from Pondicherri (loc. cit., Pl. XVI, Fig. 3), the space between the posterior margin and the keel which runs downwards from the umbo, is simply rounded, and shows neither the strong middle rib nor the fine radiating lines which characterize this part of the shell in *Trigonoarca galdrina*. *Trigonoarca gamana*, Stoliczka (non Forb.), (loc. cit., Pl. XX, Figs. 4, 5, Pl. L, Fig. 7), from the Utatur stage, differs from both the species named by the thicker shape, and above all by the posterior side being proportionally much wider than the anterior; this must therefore always be treated as a distinct species.

Locality, Pondicherri district, Valudayur and Trigonoarca beds.

PLICATULA SEPTEMCOSTATA, Forbes. Pl. X, Fig. 1.

1846. *Plicatula septem-costata*, Forbes, Trans. Geol. Soc., London, 2nd ser, VII, p. 155, Pl. XVIII, Fig. 4.

The two valves of the figured example are about oval in outline, irregularly lengthened in the region of the umbo; the lower valve is moderately convex, the upper somewhat concave near the umbo. Both are covered with strong, raised ribs, which bear numerous scaly lamellæ, corresponding with the thicker lines of growth. On Forbes's example only the latter are to be seen, whilst nothing is to be observed of the lamellæ upon the ribs, evidently because the upper layer of the shell is wanting. (In the oysters from the Valudayur beds the outer rough layer of the shell is nearly always lost in developing and only the inner pearly layer remains.)

Locality, ½ mile W. S. W. of Tutipet, Trigonoarca beds. Forbes's example, judging from the mode of preservation, came from the Valudayur beds.

SPONDYLUS LAMELLOSUS, n. sp., Pl. IX, Fig. 10, *a*, *b*.

This species, related to *Spondylus calcaratus*, Forb., which does not seem to be rare in the Trigonoarca beds, is distinguished by a very peculiar ornamentation. The surface of the shell has radiating folds, with numerous close set ribs having the same direction as the folds and covering them as well as the furrows between. Alternating, strong, concentric lamellæ, arise at irregular distances from one another, but soon fade away at each end. The outline of the shell is roundish, very similar to that of *Spondylus calcaratus*, but there is no example showing the umbonal region. An example of the last-named species, which Stoliczka (loc. cit., Pl. XXX, Fig. 7*a*) figures, shows also some resemblance in the ornamentation, but the ribs are somewhat finer, and instead of the strong lamellæ there are only irregular concentric folds.

Locality, Saidarampet, ¼ mile west of Rautankupam, etc., Trigonoarca beds.

The following species, not previously known from Pondicherri, are only figured to show the agreement with forms from the Trichinopoli district :—

Siliqua limata, Stol. (Vol. III, Pl. I, Figs. 12, 13), Pl. IX, Figs. 4, 5.
Pharella delicatula, Stol. (Vol. III, Pl. I., Fig. 14), Pl. IX, Fig. 8.
Baroda elicita, Stol. (Vol. III, Pl. IV, Fig. 16), Pl. IX, Fig. 7.
Cyprina cristata, Stol. (Vol. III, Pl. IX, Fig. 1), Pl. IX, Fig. 9.
Hippagus æmilianus, Stol. (Vol. III, Pl. XIV, Fig. 6), Pl. IX, Fig. 6.
Spondylus ariyalurensis, Stol. (Vol. III, Pl. XXXIII, Fig. 5), Pl. X, Fig. 2.

TEREBRATULA ARABILIS, Forbes. Pl. V, Fig. 4, *a f.*

1846. *Terebratula arabilis*, Forbes, Trans. Geol. Soc., London, 2nd ser., VII, p. 138, Pl. XVIII, Fig. 12.

This species has a broad oval shape and pretty regularly inflated valves; the foramen, which truncates the umbo of the larger valve, is proportionally small, the lateral elevations proceeding from it are rounded. The line of junction of the two valves is slightly curved, a single broad sinus, directed towards the smaller valve, is present. The delicately punctured surface of the shell shows extraordinarily fine lines of growth. Where this very fine outer layer is flaked off, another layer appears, which is distinguished by its silky gloss, and shows in the umbonal region fine radiating lines, and instead of the lines of growth is marked by very regular concentric bands, which are not in relief but form part of the structure of the shell. One sees, namely, with a lens, that each band consists of scale like lamellæ, lying one upon another, and that the imbrication of the scales is opposite in two of the contiguous bands. Consequently those bands in which the imbrication of the lamellæ is turned towards the light always show a peculiar, silky gloss. This shell structure is not known in *Terebratula depressa*, Lam., var. *cyrta*, Walker, which Stoliczka figured from the Utatur group (loc. cit. Vol. IV, Pl. II, Figs. 7-8) and among whose synonyms he also placed *Trebratula arabilis*; further the foramen is larger and the elevation of the valves somewhat greater, and there are among the lines of growth some developed into somewhat rugose thickenings. I consider therefore the two species to be different.

Locality, ¼ mile west of Rautankupam, Trigonoarca beds.

TEREBRATULA BIPLICATA, Sowerby. Pl. X, Fig. 3, *a, c.*

1873. *Terebratula biplicata*, Stoliczka, Cret. S. India, Vol. IV, Pt. I, p. 19, Pl. IV, Figs. 2—17.

The present species represented by a single example agrees completely with the type which Stoliczka has designated var. *karapaudensis* (Stol., loc. cit., Pl. IV, Figs. 5-9; the greatest resemblance is with figure 8).

Locality, ¼ mile west of Rautankupam (Trigonoarca beds).

HEMIASTER PULLUS, Stoliczka. Pl. X, Fig. 6, *a—d.*

1873. *Hemiaster pullus*, Stoliczka, Cret. S. Ind., Vol. IV, Pt. III, p. 18, Pl. II, Figs. 8, 9.

The little species of *Hemiaster*, from the Ariyalúr stage of Ariyalúr, which has been recorded and very minutely described, but not very well figured by Stoliczka,

does not appear to be rare in the Trigonoarca beds, as there are in Warth's collection six specimens, mostly very well preserved, which agree remarkably with Stoliczka's types. The figured example (the largest among the present ones) shows the peculiar form of the rather deeply depressed ambulacral zones very distinctly ; the elevation between the two posterior, short ambulacra is here somewhat more distinct than in the smaller specimens (see also Stol., Pl. II, Fig. 8, *b.*), without, however, developing a sharp ridge, as in *Hemiaster cristatus*, Stol.

Locality, ½ mile west of Rautankupam, Trigonoarea beds.

HEMIASTER TAMULICUS, n. sp. Pl. V, Fig. 5, *a—d.*

This species shows a tolerably regular oval outline, regularly rounded sides, and a proportionally inflated lower side. The part lying behind the subcentral (somewhat nearer the posterior side) apex is distinctly higher than the part in front, inclining at first steeply, and overhanging in the region of the anus. The whole surface is covered with closely set granules, which are largest near the mouth. The ambulacra are depressed to a moderate depth and somewhat narrow. The anterior furrow is the longest but disappears before it reaches the periphery; the two ambulacral furrows on each side of it diverge from one another at an angle of about 90°, are very little curved, broadly club-shaped and show about 16 pairs of pores. The posterior ambulacra are oval, considerably shorter than all the others and separated from each other by a rounded elevation. The ambulacral region is surrounded by a fasciole, which, owing to the considerable length of the anterior furrow, appears to be much elongated. The new species is very easily distinguished from the one associated with it, *Hemiaster pullus*, Stol., by the simple oval outline, the slight depth of the ambulacra, and the narrowness of the anterior furrow, which does not reach the margin. Among the remaining forms of the Indian cretaceous there is none with which this species could be confounded.

The related species *Hemiaster soulieri*, Fallot,[1] from the senonian beds of Dieulefit (France), is proportionally less high, the anterior ambulacra are broader and longer.

Locality, ½ mile west of Rautankupam, Trigonoarca beds.

Animal groups other than those above described are only sparingly represented in the fauna of Pondicherri.

Of bryozoa there is only one species (*Lunulites*, sp.). Corals are very rare, and owing to the sandy nature of the matrix, mostly badly preserved; annelids are represented by two species, *Ditrupa longissima*, Forbes, and *Serpula filiformis*, Sow., the latter of which (Pl. X, Fig. 7) was also known in the Ariyalúr stage of Karapadi.

On the other hand, the sandy limestone of the Nerinea beds of the uppermos division of the cretaceous is completely filled with well preserved foraminifera among which the genus *Orbitoides* (Pl. X, Figs. 8-10) is particularly striking by its great frequency. As Stoliczka was also able to prove the existence of this genus in the Niniyur beds of Niniyur, Trichinopoli district (*Orbitoides faujassi*,

[1] Fallot, Terr. crétacée dans le Sud—Est. de la France : Annales des. Sciences Géologiques. Paris, XVIII, 1885, p. 258, Pl. VIII, Figs. 2, 3.

Lam.; Stol., Cret. S. Ind., Vol. IV, Pt. IV, p. 61, Pl. XII, Figs. 3-5), this circumstance increases the agreement which exists already elsewhere between the two groups of beds. Of other sections of foraminifera a few are specially remarkable; they seem to indicate the genus *Amphistegina* (Pl. V, Figs. 11, 12).

GENERAL LIST OF PONDICHERRI FOSSILS.

The following list comprises, besides the fossils represented in Dr. Warth's collection also those described by Forbes, d'Orbigny and Stoliczka. A reference to the descriptions and figures of them by the individual authors is, I think, not necessary, as they are all easily to be found in the complete list of Stoliczka's Monograph. Species which are not known for certain to have been found in Pondicherri (as, for instance several echinoderms described by Forbes) are not taken into consideration. The arrangement of the Pondicherri cretaceous into three different horizons succeeded tolerably well with all the more important fossils, especially in the greater number of species established by Forbes, which I myself had the opportunity of seeing. As to the fossils described by Stoliczka, the remarks made by him upon the character of the rock and the association of the fossils are in the most cases sufficient to enable the horizon to be recognized. D'Orbigny's species, putting aside those found also in more recent collections, could not be provided with a definite horizon. In the table of foreign localities the description of the species compared could not be cited for want of space; I therefore quote here the works in which the most important are to be found; others are mentioned in the palæontological part of this paper.

The following is a list of the principal papers containing descriptions and figures of the foreign fossils, mentioned in the following table of the Pondicherri cretaceous fauna :—

EUROPE . . .	*A. de Grossouvre*, Les Ammonites de la Craie supérieure: Mémoires pour servir a l' explication de la Carte géologique détaillée de la France. Paris, 1893.
	A. d'Orbigny: Prodrôme de Paléontologie, Paris. 1852. Vol. II.,
	„ „ Terrains Crétacés, Paléontologie Française.
NATAL . . .	*C. L. Griesbach*, Geology of Natal: Quart. Journ. Geol. Soc., London, XXVII, 1871, p. 60 ff.
YESSO . . .	*M. Yokoyama*, Verstein. a. d. Japan. Kreide: Palæontographica, XXXVI, 1890.
	K. Yimbo, Kreide format. v. Hokkaido: Palæontologische Abhandlungen, VI. pt. 3. Jena, 1894.
VANCOUVER . .	*T. F. Whiteaves*, on the Fossils of the Cretaceous Rocks of Vancouver and adjacent Islands: Geol. and Nat. Hist. Surv., Canada. Mesozoic Fossils, Vol. II. Montreal, 1879.
QUIRIQUINA ISLAND .	*G. Steinmann*, Das Alter und die Fauna der Quiriquinaschichten in Chile: Neues Jahrbuch, Beilageband. X. Stuttgart, 1895.

Name.	Pondicherri District.			Trichinopoli District.		Foreign localities.	Age.
	Valudayur-beds.	Trigonoarca-beds.	Nerinea-beds.	Locality.	Stage.		
Phylloceras surya, Forbes . . .	x	...	...	. . . . . .	...	S. Vincente (Chile) . . .	Upp. senon.
" *nera*, Forbes . . .	x	...	...	. . . . . .	...	Vancouver; allied species in Japan, Quiriquina Island, Europe.	Senon.
" *decipiens*, Koss. . .	x						
" *forbesianum*, Koss. . .	x	...	...	A nearly allied species at Odiam.	U	Vancouver	Upp. senon.
Lytoc. (*Gaudryceras*) *kayei*, Forbes .	x	...	...	. . . . . .	...	Natal, Quiriquina Island; allied species in Vancouver and Europe.	Upp. senon.
" " *valudayurense*, Koss.	x						
" " *varuna*, Forbes.	x	...	...	. . . . . .	...	Quiriquina Island . . .	Upp. senon.
" (*Tetragonites*) *cala*, Forbes .	x	x					
" (*Pseudophyllites*) *indra*, Forbes.	x	...	...	. . . . . .	...	Natal, Vancouver; allied: *A. colloti*, Gross, in France.	Upp. senon.
Anisoceras indicum, Forbes . .	x	?	...	Odiam?	U?		
" *subcompressum*, Forbes .	x						
" *largesulcatum*, Forbes .	x	...	...	. . . . . .	...	*Hamites sp.* Jimbo, loc. cit. pl. VII, fig. 7 (Yesso).	?
" *tenuisulcatum*, Forbes .	x	...	...	Olapadi (not figured) . .	A		
" *rugatum*, Forbes . .	x	...	...	. . . . . .	...	Allied species occur in Vancouver, Quiriquina, Yesso, Europe (*H. cylindraceus*).	Upp. senon.

„ *neries*, Forbes	×						
„ *undulatum*, Forbes	×						
„ *sp. nov. ind.*, Stol.	×						
Ptychoceras sipho, Forbes	×						
Baculites teres, Forbes	×						
„ *vagina*, Forbes	×	×	...		...	Quiriquina Isl.; allied species in Europe, Vancouver, etc.	Upp. senon.
„ *vagina*, var. *otacodensis*, Stol.	×	...	...	Otacod.	A		
Sphenodiscus siva, Forbes	×	...	...		...	Allied to *Sph. ubaghsi*, Gross., in Europe; *Sph. lenticularis*, Ow. in N. America.	Upp. senon.
Holcodiscus indicus, Forbes	×						
Holcodiscus sp. nov. (undescribed, coll. Kaye).	×	...	...	Allied to a new species from Karapadi.	A		
Amm. (*n. g.*) *brahma*, Forbes	×	×	...	Otacod	A	Allied to *Amm. haugi*, Seunes, in France.	Upp. senon.
„ *vishnu*, Forbes	×						
Pachydiscus ganesa, Forbes	×						
„ *egertoni*, Forbes	×	...	...	Ariyalú r	A	*Pachydiscus neubergicus*, Hauer in Europe is perhaps the same species.	Upp. senon.
„ *crishna*, Forbes	×	...	...		...	Nearly allied to *P. gollevillensis*, Orb.	Upp. senon.
„ *gollevillensis*, Orb.	...	×	...		...	France, Ireland	Upp. senon.
„ *sp. ind.*	×						
„ *menu*, Forbes	×	...	...	Allied to *P. ariyalurensis* Stol.	A	A nearly allied species (undescribed) occurs in Neuberg (Eastern Alps).	Upp. senon.

Abbreviations: U=Utatur stage. T=Trichinopoli stage. A=Ariyalúr stage.

Name.	Pondicherri District.			Trichinopoli District.		Foreign localities.	Age.
	Valudayur beds.	Trigonoarca beds.	Nerinea beds.	Locality.	Stage.		
Pusosia rembda, Forbes	×	...	...	Allied to *Pusosia gardeni*, Baily, (Karapadi, etc.)	A	Natal; allied species in Vancouver, Yesso, Europe.	Upp. senon.
Desmoceras yama, Forbes	×						
" *diphylloide*, Forbes	×	...	...	Otacod	A	Allied to *Am. selwynianus*, Whiteaves, Vancouver.	Upp. senon.
Scaphites cunliffei, Forbes	×	...	...	. . . . . .	...	Allied to *Scaphites constrictus* Sow, Europe.	Senon.
" *pavana*, Forbes	×						
Nautilus valudayurensis, Forbes	×						
" *sphæricus*, Forbes	...	...	×	Ariyalúr, Shillagadi, etc.	A		
" *sp. nov.* (*clementinus*, Blanf.)	...	×	...	Ariyalúr, Karapadi, etc.	A		
" *sublævigatus*, Orb.	...	×	...	Ariyalúr, Shillagadi	A	Europe	Turon.
" *danicus*, Schl.	...	...	×	Niniyúr, Senthuray	A	Europe	Danian.
" *serpentinus*, Blanf.	...	...	×				
" *tamulicus*, Koss.	...	...	×				
" (*Aturia*) *delphinus*, Forbes	...	...	?				
Belemnites sp.	...	×					
Pugnellus uncatus, Forbes	×	×	...	Ariyalúr, Kalligadi, Anapadi, etc.	A, T	Quiriquina Island	Upp. senon.
Aporrhais securifera, Forbes	×	...	...	Ariyalúr, Karapadi, Anapadi, etc.	A, T		

Rostellaria palliata, Forbes . .	×	×	...	Ariyalúr, Karapadi, Serdamangalam, etc.	A, T
Cypræa newboldi, Forbes . . .	...	×	...	Andur, Kalligadi . . .	A, T
" *cunliffei*, Forbes . . .	....	×	...	Varagur	A
" *globulina*, Stol. . . .	...	×			
" *kayei*, Forbes . . .	...	×	...	Ariyalúr, Andur, etc. . .	A, T
Dipsacus vetustus, Forbes . . .	×				
Gosavia indica, Stol. . . .	×	×	...	Kalligadi, Serdamangalam, etc.	A, T
Melo pyriformis, Forbes . . .	?	×	...	Kalligadi	A
Ficulopsis pondicherrensis, Forbes .	×	...	...	Kalligadi	A
Athleta purpuriformis, Forbes . .	×	...	...	Kalligadi, Varagur . . .	A, T
Volutilithes muricata, Forbes . .	×	×	...	Kalligadi	A
" *radula*, Forbes . .	×	×	...	Kalligadi	A
" *septemcostata*, Forbes .	?	...	...	Ariyalúr	A
Triton alatus, Forbes . . .	?				
Hindsia eximia, Stol. . . .	×	...	...	Ariyalúr, etc.	A
Mitreola citharina, Forbes . .	×				
Hemifusus cinctus, Forbes . .	?	...	...	Andur, etc.	T
Pollia pondicherrensis, Forbes . .	×	...	...	Anapadi, Varagur . . .	T
" *fluctuosa*, Forbes . . .	...	×			
Neptunea (?) *subbuccinoides*, Orb. .	?				
Trichotropis, sp.	...	×			
Cancellaria breviplicata, Forbes .	?	...	...	Ariyalúr, etc.	A
" *camdeo*, Forbes . .	?	...	...	Comarapalaiam	A

NAME.	Pondicherri District.			Trichinopoli District.		Foreign localities.	Age.
	Valudayur beds.	Trigonoarca beds.	Nerinea beds.	Locality.	Stage.		
Nerinea sp.	...	...	×	Niniyur ?	A ?		
Cerithium arcotense, Forbes	×	...	...	Cuthur, Otacod, etc.	A		
" *sphæruliferum*, Forbes	?						
" *scalarioideum*, Forbes	×	...	...	Ariyalúr, Comarapalaiam	A		
" *fontanieri*, Orb.	?						
" *karasurense*, Koss.	...	×	?				
" *inauguratum*, Stol.	...	?	...	Comarapalaiam, Karapadi, etc.	A		
Turritella pondicherrensis, Forbes	×	?	...	Ariyalúr	A		
" *ventricosa*, Forbes	×						
" *breantiana*, Orb.	...	×	...	Otacod, Sripermatur, Varagur	A, T	Natal	Senon.
" *warthi*, n. sp.	×					Allied to *T. quadricincta* Goldf. (Germany).	Senon.
Scala subturbinata, Orb.	...	?	...	Ariyalúr	A		
Vermiculus anguis, Forbes	×						
Eulima antiqua, Forbes	×						
Euspira pagoda, Forbes	×	×	...	Andur	A		
" *obliquestriata*, Forbes	...	?					
Gyrodes munitus, Forbes	...	?					
Tectura (?) *elevata*, Forbes	×						
Helcion corrugatum, Forbes	×						

Nerita divaricata, Orb.	×	×	..	Parcheri	A		
Phasianella incerta, Forbes	×	...	...	Karapadi, Varagur, etc.	A, T		
Uvanilla rajah, Forbes	×						
Trochus arcotensis, Forbes	×						
Teinostoma cretaceum, Orb.	×	...	...	Comarapalaiam	A		
Solariella radiatula, Forbes	×	...	...	Ariyalúr, Karapadi, etc.	A	Sachalin, Europe (Aachen)	Senon.?
Delphinula (?) *rotelloides*, Forbes	×						
Bullina cretacea, Orb.	×						
„ *alternata*, Orb.	×	...	...	Garudamangalam, Varagur	T		
„ *sp.*	×						
Bullinula obtusiuscula, Stol.	?	...	...	Ariyalúr	A		
Actæon curculio, Forbes	×	...	...	Comarapalaiam	A		
Actæonina columnaris, Stol.	×						
Ringicula labiosa, Forbes	×	?	...	N. of Karapadi	A		
Euptycha larvata, Stol.	...	×	...	Comarapalaiam	A		
„ *oviformis*, Forbes	?	...	...	Serdamangalam, Koloture	T		
Leptomaria indica, Forbes	?	...	...	Ariyalúr, Comarapalaiam, Odiam?	A, U ?		
Dentalium arcotinum, Forbes	×	...	...	Garudamangalum	T		
„ *crassulum*, Stol.	×	...	...	Ariyalúr, Garudamangalam	A, T		
Fustiaria parvula, Stol.							
Teredo glomerans, Stol.	...	...	×	Comarapalaiam	A		
Gastrochæna aspergilloides, Forbes	?						
Clavagella semisulcata, Forbes	×						
Corbula parsura, Stol.	×	...	...	Garudamangalam	T	Gabun (W. Africa)	Senon.

NAME.	PONDICHERRI DISTRICT.			TRICHINOPOLI DISTRICT.		Foreign localities.	Age.
	Valudayur beds.	Trigonoarca beds.	Nerinea beds.	Locality.	Stage.		
Corbula cf. *striatuloides*, Forbes	×	...	...	Garudamangalam	T		
„ *minima*, Orb.	?	...	...	Odiam	U		
Neæra mutua, Stol.	×	...	...	S. of Parcheri	A		
Peromya lata, Forbes	×	...	...	Garudamangalam	T		
„ *globulosa*, Forbes	?	...	...	Comarapalaiam	A	Allied to *P. papyracea*, Böhm. (Maëstricht, Aachen).	Senon, Danien.
Corimya pertusa, Stol.	×						
Ceromya subsinuata, Forbes	×	×					
Anatina arcuata, Forbes	×						
Pholadomya lucerna, Forbes	×	×	...	Parcheri, Serdamangalam	A, T	Allied to *Ph. caudata*, Römer (Germany).	Senon.
„ *connectans*, Forbes	×						
Panopæa orientalis, Forbes	×	×	...	Ariyalúr, Serdamangalam	A, T		
Siliqua limata, Stol.	×	...	...	Parcheri, Serdamangalam	A, T		
Pharella delicatula, Stol.	×	...	...	Parcheri	A		
„ *obscura*, Forbes	×						
Tagelus albertinus, Orb.	?	...	...	Comarapalaiam	A		
Tellina pondicherrensis, Forbes	×						
„ *forbesiana*, n. sp.	×						
Baroda elicita, Stol.	×	...	...	Karapadi	A		
Thetironia ignobilis, Stol.	×						

Cyprina cristata, Stol.	×	...	...	Ariyalúr	A		
Cyprimeria obesa, Orb.	?	×	...	Niniyur	A		
Cardium cf. *pullatum*, Forbes	×	...	...	Vailapadi, Anapadi	T		
Protocardium bisectum, Forbes	×	×	...	Mongalpadi	U		
„ *pondicherrense*, Forbes.	?	...	...	Anapadi, etc.	T		
Lucina fallax, Forbes	?	...	...	Maravattur, Niniyur	U, A		
Hippagus æmilianus, Stol.	...	×	...	Sripermatúr	A		
Grotriana jugosa, Forbes	?	...	...	Odiam	U		
Cardita orbicularis, Forbes	?	...	...	Niniyur	A		
„ *striata*, Forbes	?						
Trigonia orientalis, Forbes	×	...	...	Comarapalaiam	A		
„ *suborbicularis*, Forbes	?						
Yoldia striatula, Forbes	×	...	...	Karapadi	A	Vancouver	Upp. senon.
Nucula indefinita, Forbes	×	...	...	Niniyur	A		
Axinea subauriculata, Forbes	×	...	...	Kananor	A		
„ *levicula*, Stol.	?	...	...	Ariyalúr	A		
„ *cardioides*, Orb.	?	...	...	Odiam, Serdamangalam	U, T		
Macrodon japeticum, Forbes	×	×	...	Ariyalúr, Otacod	A	Sachalin ?	?
Trigonoarca galdrina, Orb.	×	×	...	Serdamangalam, Sripermatúr	A		
„ *gamana*, Forbes	?						
„ *abrupta*, Forbes	×	×	...	Serdamangalam	T		
„ *brahminica*, Forbes.	?	?	...	Ariyalúr, Karapadi	A		
Anomalocardia clellandi, Forbes	×						
„ *pondiceriana*, Orb.	?	...	...	Serdamangalam, Shillagudi	A		

Name.	Pondicherri District. Valudayur beds.	Pondicherri District. Trigonoarca beds.	Pondicherri District. Nerinea beds.	Trichinopoli District. Locality.	Trichinopoli District. Stage.	Foreign localities.	Age.
Modiola polygona, Forbes	×						
" *flagellifera*, Forbes	×	...	...	. . . . . .	...	Allied to *M. flagellifera*, Zittel (non Forb.); Gosau.	Senon.
" *nitens*, Forbes	?	...	...	Olapadi	A		
" *cypris*, Forbes	?	...	...	= *M. typica* ? Forb. (Serdamangalam).	T		
Pinna arata, Forbes	×	...	...	Anapadi	T		
" *consobrina*, Orb.	?						
" *laticostata*, Stol.	×	...	...	Comarapalaiam, etc.	A(U ?)		
" *complanata*, Stol.	?	...	...	Anapadi, etc.	T		
Avicula nitida, Forbes	×	...	...	Comarapalaiam	A		
Gervillia solenoides ?, Defr.	?	...	...	. . . . . .	...	Europe	Upp. cret.
Janira quinquecostata, Sow.	?	...	...	div. loc.	A,T,U	Europe	Upp. cret.
Plicatula septemcostata, Forbes	?	×					
Spondylus calcaratus, Forbes	...	×	...	Serdamangalam	T		
" *ariyalurensis*, Stol.	...	×	...	Mallur	A		
" *lamellosus*, Koss.	...	×					
Exogyra ostracina, Lam.	×	×	...	Ariyalúr, Mallur	A	Borneo, Europe	Senon
Ostrea sp.	...	...	×				
Alectryonia ungulata, Lam.	×	×	...	Otacod	A	Europe, S. Africa, Madagascar, etc.	Senon.

Anomia sp.	×						
Terebratula arabilis, Forbes	...	×					
„ *biplicata*, Sow.	...	×	...	Karapadi, Varagur	A, T	Borneo, Europe	Upp. cret.
Lunulites sp.	×						
Hemiaster rana, Forbes	...	×					
„ *sexangulatus*, Orb.	...	×					
„ *pullus*, Stol.	...	×	...	Karapadi	A		
„ *tamulicus*, Koss.	...	×					
Stigmatopygus elatus, Forbes	×	...	...	Otacod, etc.	A		
Ophiura cunliffei, Forbes	?						
Serpula filiformis, Sow.	×	...	...	Ariyalûr	A	Europe	Upp. cret.
Ditrupa? longissima, Forbes	×						
Cyclolites conoidea, Stol.	...	...	×				
„ *facata*, Stol.	...	?	...	Varagur	A		
„ *filamentosa*, Forbes	...	×	?				
Caryophyllia arcotensis, Forbes	...	...	×				
Cladocera sp.	...	?					
Orbitoides sp.	...	...	×	*Orbitoides Faujassi?* Lam. in Niniyur.	A		
Amphistegina?	...	...	×				
Otodus sp.	...	×					
Odontaspis constrictus, Eg.	...	?	...	Utatur	U		
Crustacea (Forbes)	...	?					

EXPLANATION OF PLATES.

PLATE VI.

Fig. 1.—*Pachydiscus gollevillensis*, Orb.—*a*, side view; *b*, back view; *c*, sutures from the same specimen; ½ mile W. of Rautankupam, Trigonoarca beds.

Fig. 2.—*Pachydiscus ganesa*, Forbes.—*a*, side view; *b*, front view; *c*, sutures from the same specimen; ½ mile N. of Tutipet, Valudayur beds.

Fig. 3.—*Pachydiscus* sp. aff. *gollevillensis*, Orb.—*a*, side view; *b*, front view, enlarged $\frac{2}{1}$; *c*, sutures from the same specimen; ½ mile N. of Tutipet, Valudayur beds.

Fig. 4.—*Baculites vagina*, Forbes.—*a*, side view; *b*, ventral view; *c*, section from the same specimen; Rayapudupakam, Trigonoarca beds.

Fig. 5.—*Nautilus tamulicus*, sp. nov.—Back view of a septum; Kadaperikupam ?, Nerinea beds.

Fig. 6.—*Nautilus tamulicus*; sp. nov.—Section; Saidarampet, Nerinea beds.

Fig. 7.—*Belemnites sp.* (= *Belemnites fibula*, Forbes).—*a*, side view; *b*, section; ½ mile N. N. W. of Rautankupam, Trigonoarca beds.

Fig. 8.—*Pugnellus uncatus*, Forbes.—Back view of a cast; ½ mile W. of Rautankupam, Trigonoarca beds.

PLATE VII.

Fig. 1.—*Nautilus tamulicus*, sp. nov.—Side view; Saidarampet, Nerinea beds.

Fig. 2.—*Volutilithes muricata*, Forbes.—Front view; ½ mile W. of Rautankupam, Trigonoarca beds.

Fig. 3.—*Gosavia indica*, Stoliczka.—*a*, front view; *b*, back view; ½ mile N. N. E. of Rautankupam, Valudayur beds.

Fig. 4.—*Euptycha larvata*, Stoliczka.—*a*, front view; *b*, back view; Rayapudupakam, Trigonoarca beds.

Fig. 5.—*Cerithium karasurense*, sp. nov.—*a*, front view; *b*, back view of the last whorl; Karasur, Trigonoarca beds.

Fig. 6.—*Cerithium* cf. *karasurense*, sp. nov.—*a*, back view; *b*, section of another specimen; Saidarampet, Nerinea beds.

Fig. 7.—*Nerinea sp.*—Section of a whorl; 1½ mile S. S. E. of Valudayur, Nerinea beds.

PLATE VIII.

Fig. 1.—*Nerinea sp.*—Front view, natural size; 1½ mile S. S. E. of Valudayur, Nerinea beds.

Fig. 2.—*Trichatropis* aff. *konnicki*, Müller.—*a*, back view; *b*, front view; ½ mile W. S. W. of Tutipet, Trigonoarca beds.

Fig. 3.—*Turritella warthi*, sp. nov.—*a*, back view enlarged; *b*, fragment from the same locality; ½ mile N. of Tutipet, Valudayur beds.

Fig. 4.—*Trochus arcotensis*, Forbes.—*a*, top; *b*, basal; *c*, side view; N. N. W. of Tutipet, Valudayur beds.

Fig. 5.—*Teinostoma cretaceum*, Orb.—*a*, top; *b*, basal; *c*, side view; ½ mile N. of Tutipet, Valudayur beds.

Fig. 6.—*Bullina cretacea*, Orb.—*a*, front view; *b*, back view; ½ mile N. of Tutipet, Valudayur beds.

Fig. 7.—*Bullina sp.*—*a*, front view; *b*, back view; 1 mile N. N. W. of Tutipet Valudayur beds.

Fig. 8.—*Dentalium crassulum*, Stol.—*a*, side view; *b*, section; 1 mile N. N. W. of Tutipet, Valudayur beds.

Fig. 9.—*Pholadomya lucerna*, Forbes.—Side view; ½ mile W. S. W. of Tutipet, Trigonoarca beds.

Fig 10.—*Pholadomya lucerna*, Forbes.—*a*, side view; *b*, umbonal view; 1 mile S. S. E. cf Pulichapalaam, lower Valudayur beds.

PLATE IX.

Fig. 1.—*Trigonoarca galdrina*, Orb.—*a*, side view; *b*, inner view; 1 mile N. N. W. of Tutipet, Valudayur beds.

Fig. 2.—*Trigonoarca galdrina*, Orb.—Side view; ½ mile W. S. W. of Tutipet, Trigonoarca beds.

Fig. 3.—*Trigonoarca galdrina*, Orb.—*a*, side view; *b*, inner view; 1 mile N. of Saidarampet, Trigonoarca beds.

Fig. 4.—*Siliqua limata*, Stol.—Side view; 1 mile E. S. E. of Pulichapalam, lower Valudayur beds.

Fig. 5.—*Siliqua limata*, Stol.—Side view; ½ mile N. of Tutipet, Valudayur beds.

Fig. 6.—*Hippagus æmilianus*, Stol.—*a*, side view; *b*, front view of a cast; ½ mile W. of Rautankupam, Trigonoarca beds.

Fig. 7.—*Baroda elicita*, Stol.—Side view; 1 mile E. S. E. of Pulichapalaam, lower Valudayur beds.

Fig. 8.—*Pharella delicatula*, Stol.—Side view; ¾ miles S. E. of Wottai, Valudayur beds.

Fig. 9.—*Cyprina cristata*, Stol.—Side view; ½ mile W. of Rautankupam, Trigonoarca beds.

Fig. 10.—*Spondylus lamellosus*, sp. nov.—*a*, side view; *b*, back view; Saidarampet ?, Trigonoarca beds.

Fig. 11.—*Corbula parsura*, Stol.—*a*, side view; *b*, umbonal view; ½ mile N. of Tutipet, Valudayur beds.

Fig. 12.—*Tellina forbesiana*, sp. nov.—*a*, side view; *b*, umbonal region, enlarged; *c*, umbonal view; 1 mile N. N. W. of Tutipet, Valudayur beds.

Fig. 13.—*Tellina pondicherrensis*, Forbes.—Side view; ½ mile N. of Tutipet, Valudayur beds.

Fig. 14.—*Tellina pondicherrensis*, Forbes.—*a*, side view; *b*, umbonal view; ½ mile N. of Tutipet, Valudayur beds.

PLATE X.

Fig. 1.—*Plicatula septemcostata*, Forbes.—*a*, lower valve; *b*, upper valve; ½ mile W. S. W. of Tutipet, Trigonoarca beds.

Fig. 2.—*Spondylus ariyalurensis*, Stol.—*a*, side view; *b*, back view; ½ mile W. S. W. of Tutipet, Trigonoarca beds.

Fig. 3.—*Terebratula biplicata*, Sow.—*a, b, c*, different views; ¼ mile W. of Rautankupam, Trigonoarca beds.

Fig. 4.—*Terebratula arabilis*, Forbes.—*a, b, c, d*, different views; *e*, part of the test enlarged; *f*, section through the test enlarged; ¼ mile W. of Rautankupam, Trigonoarca beds.

Fig. 5.—*Hemiaster tamulicus*, n. sp.—*a, b, c, d*, four views of a perfect specimen natural size; ¼ mile W. of Rautankupam, Trigonoarca beds.

Fig. 6.—*Hemiaster pullus*, Stol.—*a, b, c, d*, four views of a perfect specimen; ¼ mile W. of Rautankupam, Trigonoarca beds.

Fig. 7.—*Serpula filiformis*, Sow.—Natural size; ½ mile N. W. of Tutipet, Valudayur beds.

Fig. 8.—*Orbitoides sp.*—Vertical (median) section; Saidarampet, Nerinea beds.

Fig. 9.—*Orbitoides sp.*—Vertical section; 1¼ mile S.S.E. of Valudayur, Nerinea beds.

Fig. 10.—*Orbitoides sp.*—Horizontal (median) section; 1¼ mile S.S.E of Valudayur, Nerinea beds.

Figs. 11, 12.—*Amphistegina sp.*?—Vertical and horizontal section of different specimens; 1¼ mile S. S. E. of Valudayur, Nerinea beds.

Notes from the Geological Survey of India.

The occurrence of two minerals, previously unknown in India, may be recorded.

Aluminite from the Salt Range.—The first of these, aluminite, occurs in veins in the shale underlying the coal seam at Chittidand in the Salt Range and was collected by Dr. Warth in 1886. It has a chalky appearance, but under the microscope is seen to consist of small monoclinic crystals. The hardness is between degrees 1 and 2 of Moh's scale, and the sp. gr. is 1·707, being rather high on account of small quantities of admixed iron. A portion of the mineral, freed as much as possible from iron, was analysed by Mr. Hayden and found to have the following composition:—

Al_2O_3	30·08 per cent.
SO_3	23·63 „
H_2O	46·44 „
CaO	trace.
ZiO	„
Fe_2O_3	„
	100·15

hus indicating the formula $Al_2O_3, SO_3, 9H_2O$.

Altaite from Upper Burma.—The occurrence of altaite in the Choukpazat gold

mine, Wuntho, Upper Burma, is of greater interest, as it is the first recorded occurrence of a telluride in India. Found as small specks in quartz associated with free gold and auriferous pyrites, it was first identified by Professor H. Louis,[1] and an analysis subsequently made in the laboratory of the Geological Survey confirmed the identification.

Petroleum in Upper Burma.—The survey of the Yenangyat oilfield has shown that besides the exposure of pliocene beds, already being exploited, at Yenangyat there are two other exposures along the same anticlinal which may be regarded as future oilfields. One of these lies south of the Irawadi, to the south of Singu, in block 58N of the Yenangyoung oilfields survey. The other lies to the north of Yenangyat and extends from the north part of block 4 of the Yenangyat oilfields survey to about 6 miles north of the limit of this survey. This exposure is larger and beds of miocene age (Prome stage) crop out along the axis of the anticlinal, the first oil sand of the Yenangyat borings being exposed at the surface. At one place the hill is reported to have been on fire last year, the flames being about 3 feet high.

Mud-Volcano in Tipperah.—On 17th March some specimens of mud were received through the Director of Land Records and Agriculture, Bengal, from Mr. F. G. Cumming, Settlement Officer of Chakla Roshnabad, said to have been taken from "a place on the borders of the District of Tipperah, where there is at present a tiny volcanic eruption." In the same letter it is stated that the villagers said that "about thirty years ago there was a similar manifestation; and that a mound was made over the spot. All that is now visible is a flame about 6 inches high issuing from a hole in the centre of this mound, which is about five feet above the surrounding lands, which are rice fields but quite close to the frontier hills."

The dried mud sent with this letter was of the same type as that thrown out by the mud-volcanoes of Arracan and Minbu, and Mr. Cumming's account left no room for doubt that he had discovered a small mud-volcano or salse in a previously unrecorded locality. In reply to an enquiry for more precise information as to the site, Mr. Cumming reports that it is "in the centre of cultivated land at the foot of the Tipperah hills on the eastern boundary of Tipperah district, and 16 miles due north of the sadar station Comilla. The site of the little eruption is in a village called Ballabpur, and is, as far as I can calculate, in 91° 15′ 30″ east longitude and 23° 40′ 30″ north latitude. This village is not marked on the four miles to the inch district map of Tipperah, but the adjoining village Horepur is."

[1] Trans. Fed. Inst. Min. Eng., XII, 513, (1897).

DONATIONS TO THE MUSEUM.

FROM 1ST FEBRUARY TO 30TH APRIL 1897.

Three small pieces of a meteorite that fell at Nawapali, Sambalpur district, Central Provinces, on the 6th June 1890, at 6 P.M.

Sent by the Commissioner of Settlements and Agriculture, Central Provinces, Nagpur.

ADDITIONS TO THE LIBRARY.

FROM 1ST JANUARY TO 31ST MARCH 1897.

Titles of Books. *Donors.*

Becker, *G. F.*—Some queries on rock differentiation. 8° Pam., New Haven, 1897.
THE AUTHOR.

Bronn, *H. G.*—Klassen und Ordnungen des Their—Reichs. Band III, lief. 24—25; Supplement Band IV, lief. 1—4, and Band VI, Abth. V, lief. 45—46. 8° Leipzig, 1896.

Draghicénu, *Math, M.*—Les Tremblements de Terre de la Roumanie et des Pays Environnants. 8° Bucuresci, 1896. THE AUTHOR.

Mineral Statistics of the United Kingdom of Great Britain and Ireland, with the Isle of Man, for 1895. Flsc., London, 1896. GOVERNMENT OF INDIA.

Norwegian-North Atlantic Expedition, 1876-78. Vol. XXIII; Zoology, Tunicata: Synascidiæ, by H. Huitfeldt—Kaas; Ascidiæ Simplices and Ascidiæ Compositæ by Kristine Bonnevie; A list of Norwegian Ascidiæ Simplices by Johan Kiær; On gemmation in Distaplia Magnilarva and Pyrosoma Elegans by Kristine Bonnevie; and Germ-layer studies based upon the development of Ascidians by Johan Hjort. 4° Christiana, 1896. THE COMMITTEE.

O'Riley, *E.*—Report on the Mineral Resources of the Martaban District. Flsc., Calcutta, 1865. GOVERNMENT OF INDIA.

Rough conspectus of the tracts in which minerals are believed to exist in Burma, with 12 Maps. Flsc., Rangoon, 1895. GOVERNMENT OF INDIA.

Second Annual General Report upon the Mineral Industry of the United Kingdom of Great Britain and Ireland for the year 1895. By C. Le Neve Foster. Flsc., London, 1896. SECRETARY OF STATE FOR INDIA.

Stephanescu, *S.*—Carte Geologique de la Roumanie publiée par Mathi M. Draghicénu. 8° Pam., Bucuresci, 1891. THE GEOLOGICAL BUREAU.

PERIODICALS, SERIALS, ETC.

American Geologist. Vol. XVIII, No. 6 to Vol. XIX, Nos. 1—2. 8° Minneapolis, 1896-1897.

" Journal of Science. Series 4, Vol III, Nos. 13—15. 8° New Haven, 1897.
THE EDITOR.

" Naturalist. Vol. XXX, No. 360 to Vol. XXXI, Nos. 361—362. 8° Philadelphia, 1896-1897.

Annalen der Physik und Chemie. Band LX, heft. 1—2. 8° Leipzig, 1897.

Annals and Magazine of Natural History. Vol. XIX, Nos. 109—111. 8° London, 1896-1897.

Titles of Books. *Donors.*

Athenæum. Nos. 3608—3620. 4° London, 1896-1897.

Beiblätter zu den Annalen der Physik und Chemie. Band XX, Nos. 11—12, and XXI, Nos. 1—2. 8° Leipzig, 1896-1897.

Chemical News. Vol. LXXIV, No. 1934 to Vol. LXXV, No. 1946. 8° London, 1896-1897.

Colliery Guardian. Vol. LXXII, No. 1877 to Vol. LXXIII, No. 1889. Fol., London, 1896-1897.

Geological Magazine. New series, Decade IV, Vol. IV, Nos. 1—3. 8° London, 1897.

Indian and Eastern Engineer. Vol. XXVIII, Nos. 507—519. Folio, Calcutta. 1897. THE EDITOR.

Industries and Iron. Vol. XXI, No. 1249 to Vol. XXII, No. 1261. 4° London, 1896-1897.

Journal of Geology. Vols. IV, Nos. 7—8, and V, No. 1. 4° Chicago, 1896-1897.

London, Edinburgh, and Dublin Philosophical Magazine. Vol. XLIII, Nos. 260—262. 8° London, 1896-1897.

Mineralogical Magazine. Vol. XI, No. 51. 8° London, 1896.

Mining Journal. Vol. LXVI, No. 3199 to Vol. LXVII, No. 3211. Folio, London, 1896-1897.

Natural Science. Vol. X, Nos. 59—61. 8° London, 1896-1897.

Nature. Vol. LV, Nos. 1416—1428. 4° London, 1896-1897.

Neues Jahrbuch für Mineralogie, Geologie und Palæontologie. Jahrg. 1896, Band II, heft 1—3, and Jahrg. 1897, Band I, heft 1. 8° Stuttgart, 1896-1897.

" " Beilage-Band XI, heft 1. 8° Stuttgart, 1897.

Petermann's Geographische Mittheilungen. Band XLII, No. 12 to Band XLIII, Nos. 1-2. 4° Gotha, 1896-1897. THE EDITOR.

Scientific American. Vol. LXXV, Nos. 23—26, and Vol. LXXVI, Nos. 1—9. Fol., New York, 1896-1897.

" " Supplement. Vol. XLII, No. 1092 to Vol. XLIII, No. 1104. Fol., New York, 1896-1897.

Tschermak's Mineralogische und Petrographische Mittheilungen. Vol. XVI, heft 5—6. 8° Wien, 1896-1897.

Zeitschrift der Gesellschaft für Erdkunde zu Berlin. Band XXXI, heft 5—6. 8° Berlin, 1896.

" für Krystallographie und Mineralogie. Band XXVII, heft 5—6. 8° Leipzig, 1896-1897.

" für Praktische Geologie. Heft 12 (1896) and heft 1—2 (1897). 4° Berlin 1896-1897.

Zoological Record. Vol. XXXII, 1895. 8° London, 1896. THE SOCIETY.

GOVERNMENT SELECTIONS, REPORTS, ETC.

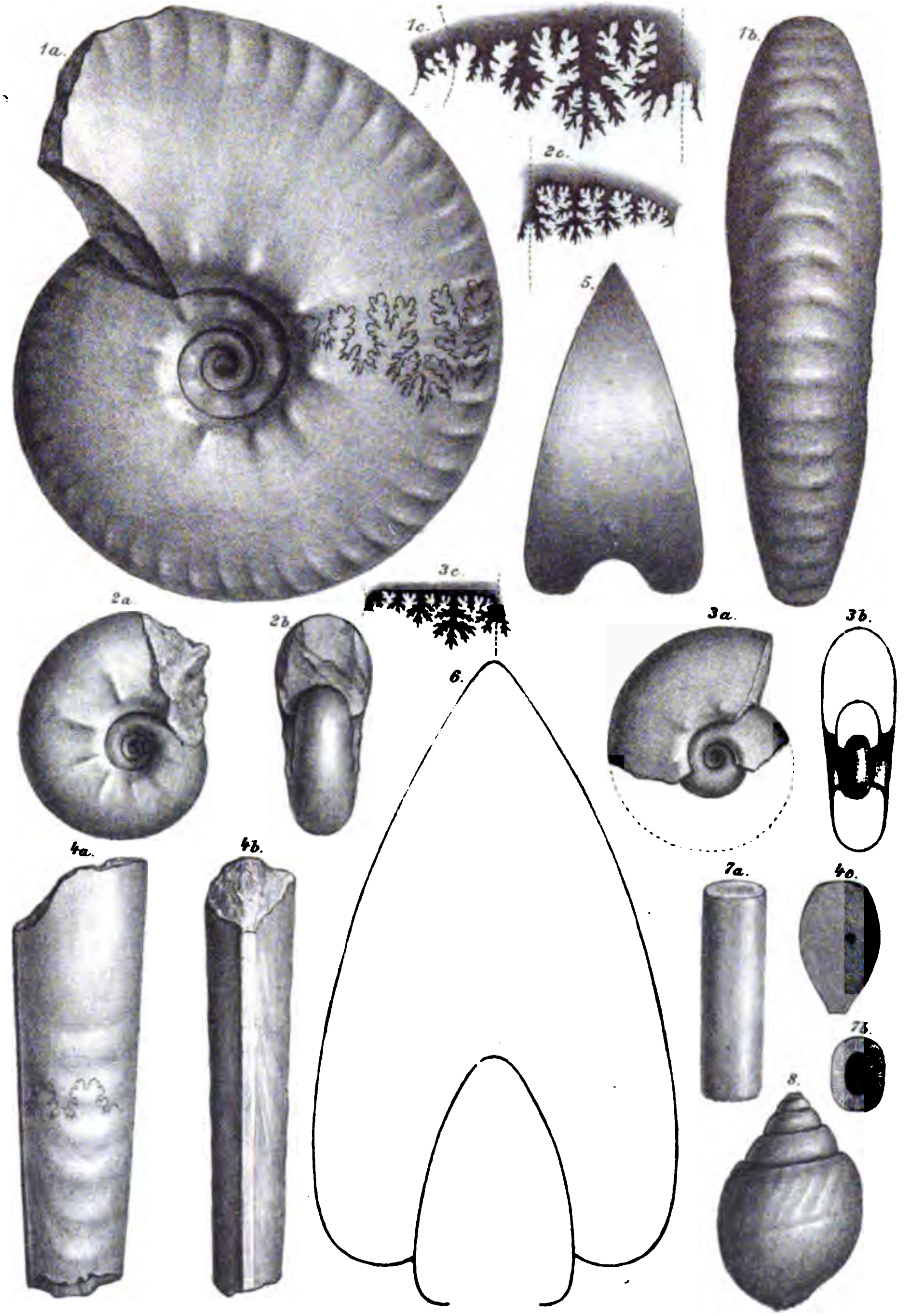
ASSAM.—Report on the Administration of the Province of Assam for 1895-96. Flsc., Shillong, 1896. CHIEF COMMISSIONER, ASSAM.

BENGAL.—Report on the Administration of Bengal, 1895-96. Flsc., Calcutta, 1896. BENGAL GOVERNMENT.

F. KOSSMAT.

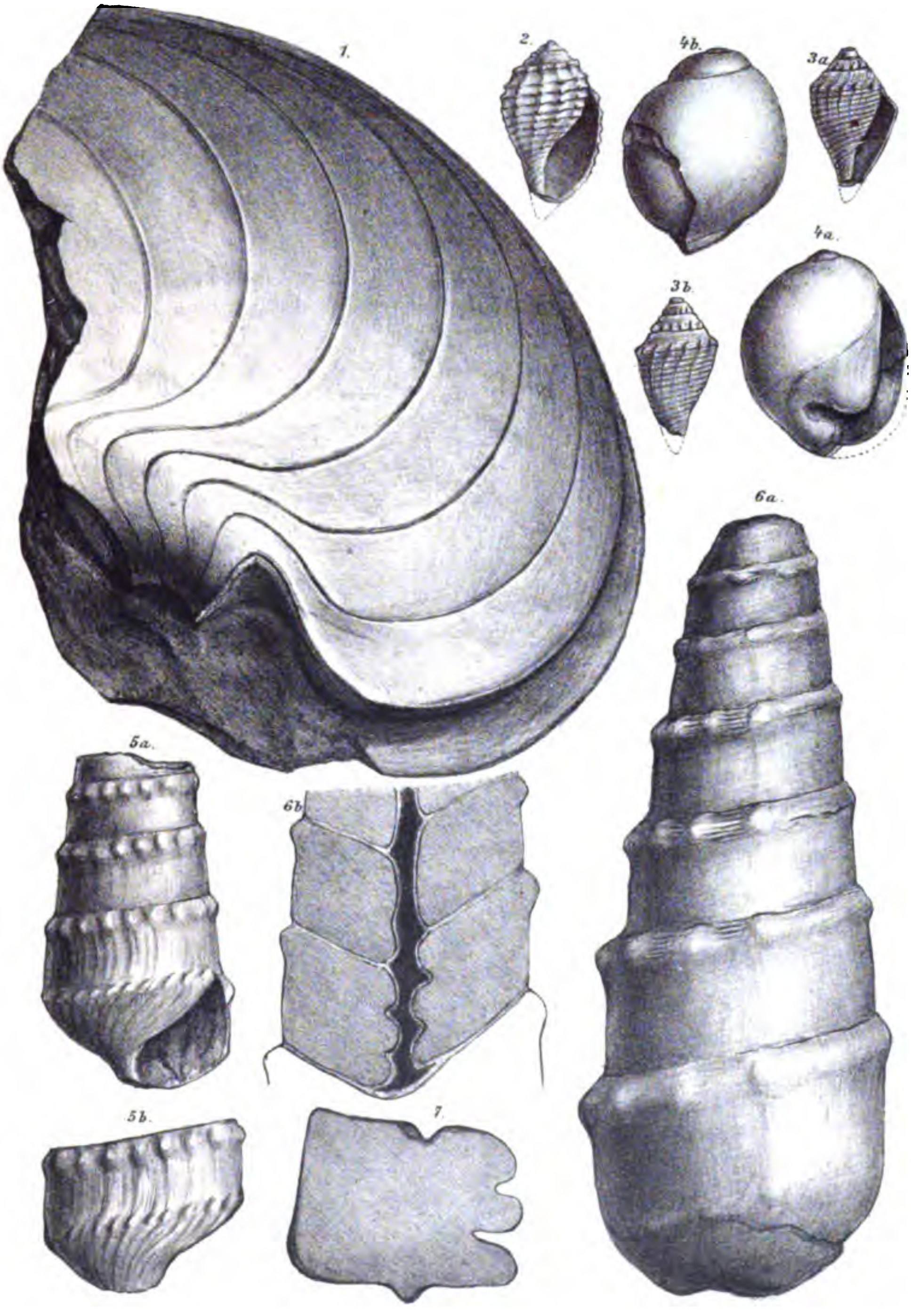
GEOLOGICAL SURVEY OF INDIA.

Records, vol. XXX. pl. VI.



A Swoboda del et lith

Th Bannwarth print.



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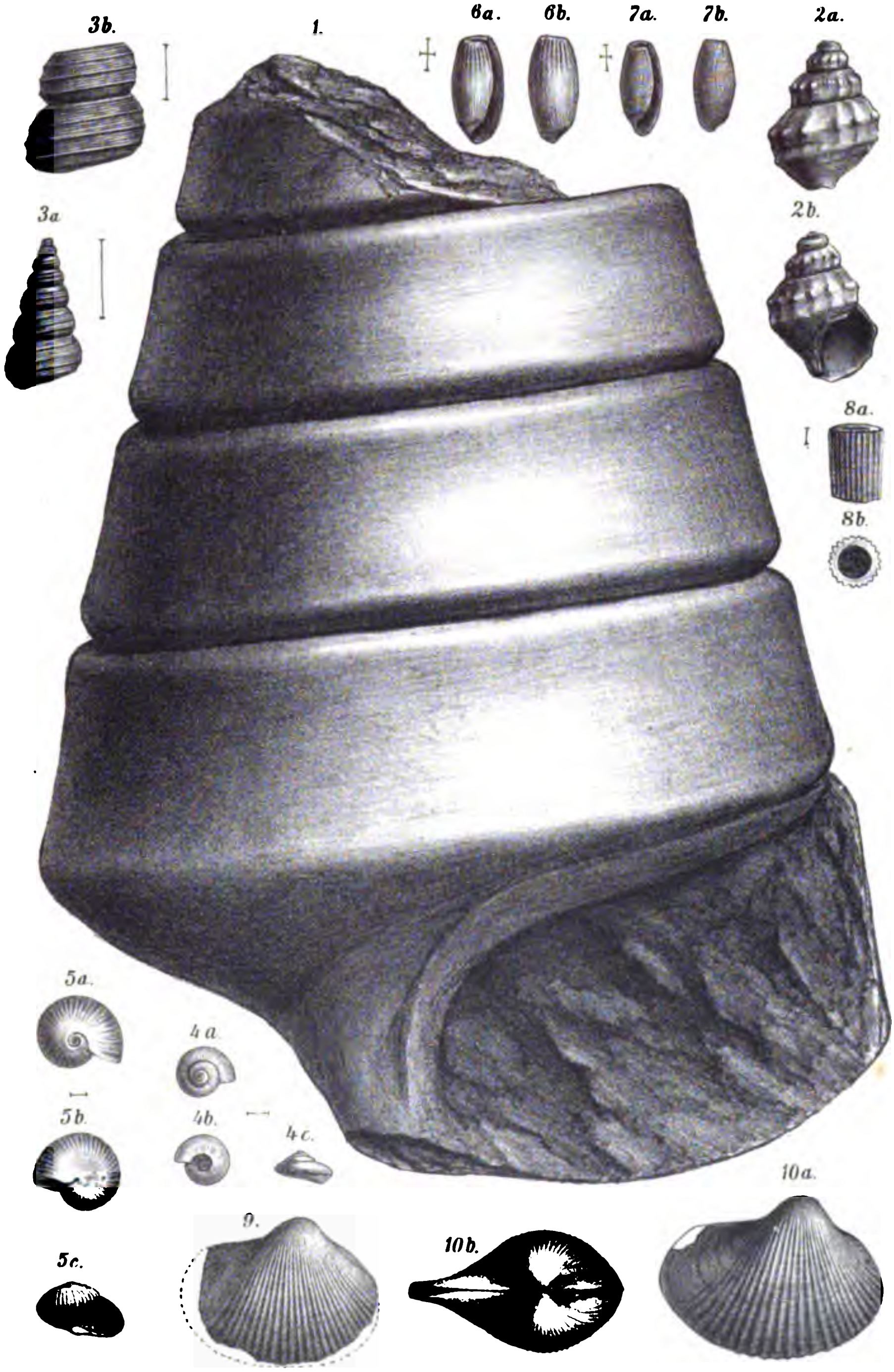

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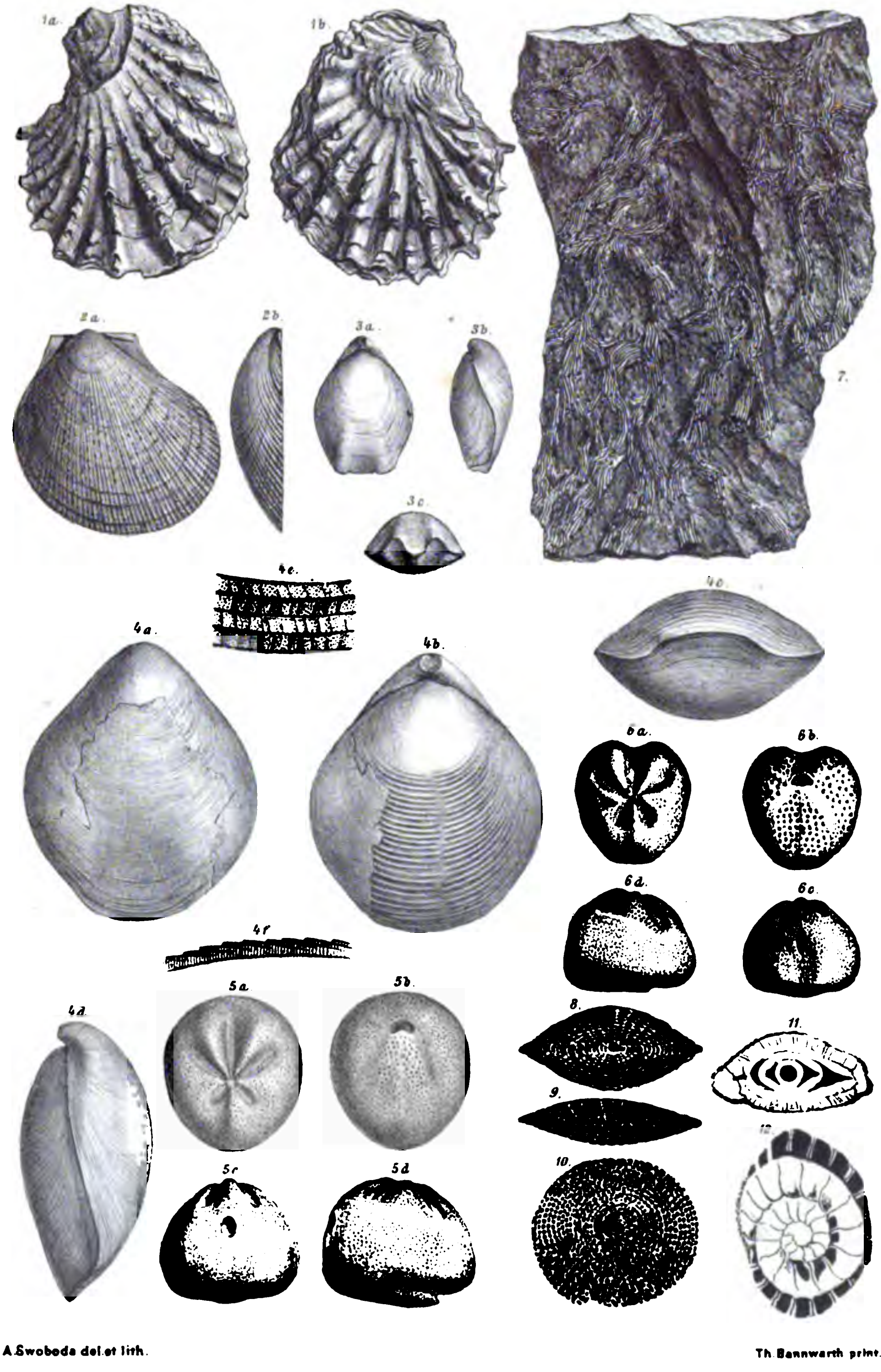

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PIPE AND RAMIFYING VEINS OF MICA PERIDOTITE IN COKE.

$\frac{2}{3}$ *Natural Size*

DYKE OF MICA PERIDOTITE WITH COLUMNAR COKE.

$\frac{1}{4}$ *Natural Size*

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3. 1897. August.

Note on Flow-structure *in an* Igneous dyke, *By* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India* (with plate XI).

Amongst the many striking proofs of the igneous nature of the dykes of "mica-trap" occurring so abundantly in the coalfields of Bengal, two specimens collected by Dr. Saise and myself in the Laikdih Colliery, near Barakar, and now preserved in the Geological Museum, Calcutta (Nos. 10-50 and 10-47), illustrate in an unusual and interesting manner the condition of the rock at the time of its intrusion.

The first specimen (No. 10-50) is a portion of a dyke with fringes of columnar coke on either side. The width of the dyke is only 8 inches, and, when found, the columnar coke extended 7 inches outwards on either side, passing into the normal coal of the bed through which the dyke was intruded. The rock is a variety of a mica-peridotite which, as I have shown in a previous note, is remarkable for the large amount of apatite it contains.[1] At the selvages of this narrow dyke the rock is seen to be perfectly compact, whilst towards the central portions the disposition of the biotite flakes in waves shows the direction in which the current was flowing just before the molten material consolidated, the viscous mass continuing to move slowly forward in the central portions of the dyke after the crystallization of much of the biotite and after the consolidation of the selvages (plate XI, fig. 1). The second specimen from the same locality (No. 10-47) shows a cross section of a pipe of mica-peridotite in coke only 2 inches in diameter, displaying the concentric arrangement of the mica flakes parallel to the edges of the circular hole through which the molten matter passed (plate XI, fig. 2).

Considering the number and size of the great intrusive sheets of this remarkable rock, and the narrowness of the dykes, which has been remarked in all the coalfields in which the rock occurs, veritable streams of molten material must have flowed along the narrow dyke fissures from below to form such extensive sheets as that which caps the coal seam at Laikdih. It is an interesting circumstance to find this inference so strikingly confirmed by such specimens of "fossilized" subterranean streams, which exhibit the usual character of streams, namely, greater freedom of movement in the centre.

I have, in the paper quoted,[2] referred to other evidences pointing to the high temperature and mobile condition in which this rock must have been at the time of

[1] *Rec. Geol. Surv. Ind.*, XXVII, 129 (1894).
[2] *Rec. Geol Surv. Ind.*, XXVII.

its intrusion, and it naturally follows that such a mobile condition of intrusion is consistent with the narrowness of the dykes compared with the great extent of the sheets and laccolitic reservoirs which have been supplied with molten material through the narrow dyke fissures.

Additional note on the Olivine-norite dykes *at* Coonoor, Nilgiri Hills. *By* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India* (with plate XII).

I.—INTRODUCTION.

1. In a paper on the basic dykes of Southern India reference was made to the interesting variations in grain exhibited by the dykes near Coonoor.[1] Since the publication of that paper opportunity has occurred for examining with greater precision the general conclusions then stated with regard to the passage of the well crystallized types, in the larger dykes, into the forms with a vitreous matrix, at the selvages and in the thin veins which ramify amongst the "pyroxene-granulites" into which the trap dykes are intruded.

II.—GEOLOGICAL CHARACTERS.

2. The dykes which have been examined at Coonoor vary in thickness from ten feet to one tenth of an inch. The widest dykes are well exposed in the cutting made for the new ghát road to Mettapalaiyam, whilst a large number, varying from two feet in thickness to thin films, are beautifully displayed on the well washed masses of rock forming the bed of the Coonoor river, immediately below the bridge. The rocks into which the dykes have intruded are varieties of the peculiar hypersthene-bearing "pyroxene-granulites," which are such prominent constituents of the main mountain masses of the Madras Presidency. At Coonoor these rocks are well foliated and generally contain large quantities of blue quartz and garnet (Nos. 9·307, 10·669 and 11·362). They include bands of large lenticular masses of pyroxene-felspar rocks, generally with biotite (Nos. 9·302, 9·303 and 11·363), through which the dykes pass, as well as through the ordinary pyroxene-granulite in which these lenticles occur. The strike of the foliation of the pyroxene-granulites is east-north-east and west-south-west, whilst the dykes run north-north-west and south-south-east, or at right angles to the foliation planes. The foliation of the pyroxene-granulites was evidently completed before the intrusion of the dykes; but since the infilling of the fissures now occupied by the "traps," small movements have occurred along the same direction, as shown by the shearing of one of the narrow dykes. The phenomena of chilled selvages, such as are described below, show that the pyroxene-granulites had previously consolidated and were comparatively cold at the time of the intrusion of the trap.

[1] *Rec. Geol. Surv. Ind.*, XXX, 25 (1897).

T. H. Holland.

Records, Vol: XXX. Plate XII.

Fig. 1.
DYKE 10 FT. WIDE.

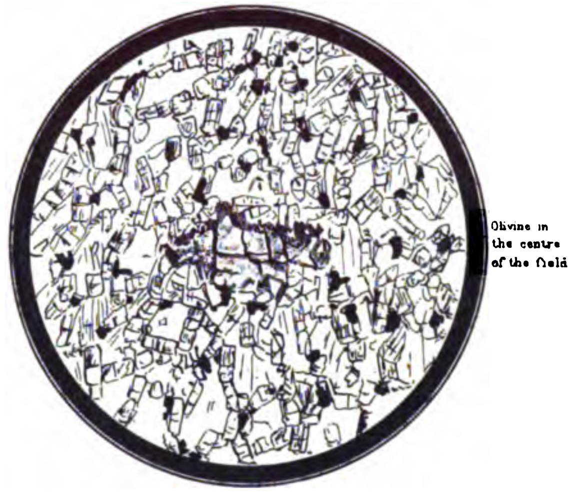


Fig. 2.
DYKE 2 FT. WIDE.

Fig. 3.
DYKE 4 INCHES WIDE.

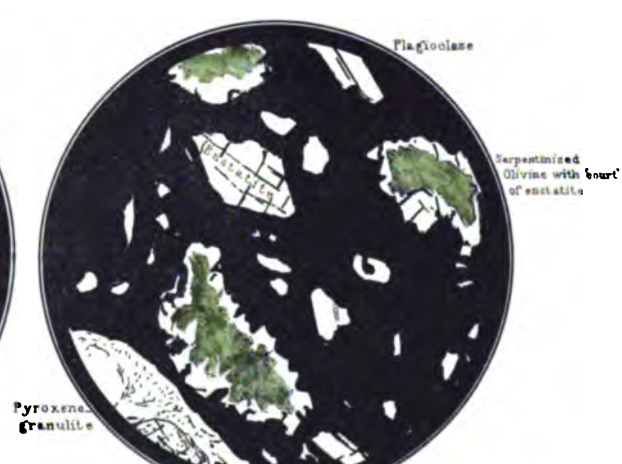


Fig. 4.
DYKE ⅛ INCH WIDE.

OLIVINE-NORITE DYKES AT COONOOR,

NILGIRI HILLS.

Magnified 20 diameters.

III.—PETROLOGICAL CHARACTERS.

3. The rocks, which show the variations in structure described below, belong, as stated in the paper already mentioned, to the group of olivine-norites, and exhibit invariably the following approximate order of consolidation of their essential constituents :—

(1) Olivine and iron ores.
(2) Enstatite.
(3) Augite.
(4) Plagioclase.

Olivine.

4. The *olivines* are remarkable for their smoky-brown colours when their inclusions are apparently of ultra-microscopic dimensions, and for their grey colour when the dusty inclusions are sufficiently large for individual recognition with the higher powers. These inclusions are arranged in parallel lines, and are almost certainly the representatives on a very minute scale of the dendritic inclusions recognised in members of this group collected in other parts of the Madras Presidency.[1] Another peculiarity, well-displayed by the olivines of the Coonoor dykes, is their ragged outline and enveloping zone of stumpy colourless enstatite crystals forming glomero-porphyritic groups. The irregular outline of each olivine is probably due to the fact that the crystallization of the enstatites commenced in its immediate precincts, before the complete crystallization of the former mineral.

Crystallization "courts."

5. In view of the known fact that a crystal exerts an influence on the magma in its immediate neighbourhood, the occurrence of these zones of enstatite round the olivines, forming glomero-porphyritic groups in the hemicrystalline varieties of the olivine-norites, is a feature of very great mineralogical interest. The "sphere," "court," or, to use an expressive Anglo-Indian term, "compound," around a crystal (*der Hof des Krystalles*) can, as shown by O. Lehmann,[2] be strikingly illustrated experimentally in cobalt-chloride solutions. Crystals of hydrated cobalt chloride ($2CoCl_2.12H_2O$) are rose-red in colour, whilst the anhydrous salt ($CoCl_2$) is blue. A solution of cobalt chloride at the ordinary temperature is rose-red in colour; but on warming, the colour changes to blue, presumably on account of the dissociation of the hydrate. The temperature at which this change takes place depends on the concentration of the solution; that is to say, the blue solution would become pink if the solution were diluted, without change of temperature. Now, when a crystal of cobalt chloride, growing in a blue solution, is watched under the microscope, it is seen to be surrounded by a pink zone, which is evidently due to the fact that the crystal, having drawn material from the zone immediately around it, has left that zone relatively more dilute than the rest of the solution, and the cobalt chloride remaining in that zone (that is, within the "court" of the crystal) exists in the more hydrated form.

The case of the olivine crystals growing in a basic magma is strictly analogous to that of the cobalt chloride. An olivine forms in a basic molten magma when the temperature is sufficiently reduced to allow of the formation of the "molecular compound" represented by the formula $2(Fe,Mg)O.SiO_2$. The

[1] *Cf. loc. cit.*, p. 24.
[2] *Zeitschr. für Kryst.*, I, 99.

removal of this basic molecular compound from the magma in the immediate vicinity of the growing olivine crystal must result in the production of a zone in which there is a relatively smaller quantity of the bases magnesia and iron, a more siliceous, more acid, or more dilute zone, and out of this more acid zone we have the higher silicate crystallized as a rim of enstatite crystals, whose composition is represented by the formula $2(Fe,Mg)O.2SiO_2$; that is, a molecular compound containing twice as much silica as the olivine. The relation which the olivine bears to the enstatite is therefore precisely similar to that which the blue crystals of cobalt chloride bear to the pink, more hydrated, form which exists in the surrounding zones, or "courts," of the crystals.

Iron ores.

6. The *iron ores* form a considerable proportion of the rocks. Besides the magnetite and titaniferous ore, a considerable proportion of the iron exists as pyrites. In the coarser grained rocks they form distinct granules with cubic outlines (11·350 and 11·351), which are noticeably smaller in the narrower dykes (11·356 and 11·353), existing as mere dust near the selvages of veins up to 3 or 4 inches in thickness (11·352) and occurring in particles of ultra-microscopic dimensions, diminishing the translucency of the glassy matrix of the minutest veins (11·352). In the last mentioned varieties of the rock the removal of the dust from the matrix immediately surrounding a crystal of magnetite, showing a narrow "court" of clear glass, is occasionally exhibited.

Enstatite.

7. In addition to its existence as a "courtier" to the olivine, *enstatite* forms isolated well shaped crystals, scattered through the rock. It frequently exhibits a very faint pleochroism—the pleochroism characteristic of rhombic pyroxenes—and sometimes forms long crystals which can be easily recognised by the naked eye in the finer grained selvage of the larger dykes and in the narrow veins (11·353). The shapes, cleavage and optical characters agree with those of a rhombic pyroxene containing a comparatively low percentage of iron, and call for no further remark.

Augite.

8. *Augite* is far less abundant than the rhombic pyroxene, which is in agreement with previous observations concerning the rocks of this class.[1] No other feature worthy of special remark has been noticed in connection with this constituent.

Plagioclase.

9. The *plagioclase* crystals, both in the glassy varieties and in those with a microcrystaline matrix, often show inlets filled with the magma. Whether these are the result of corrosion by the magma, or whether they are due to the inclusion of portions of the magma by irregularities in the growth of the felspar, is not certain. As plagioclase is the latest of the constituents to crystallize, it is more probable that the magma would be in a more viscous condition than when the ferro-magnesian silicates were separated; the increased viscosity would consequently interfere with freedom of development during the formation of the outer (younger) layers of plagioclase in each crystal, and as a result irregularity of outline would probably result. This circumstance, together with the fact that the portions of the magma protruding into the plagioclase-crystals, both in the glassy and in the microcrystalline varieties of the rock, are precisely similar in character to the general matrix, may be regarded as evidences

[1] *Cf. Rec. Geol. Surv. Ind.*, XXX, 22.

against the theory of corrosion, although the inlets in general shape and appearance are at first sight remarkably similar to the cases of presumably corroded quartz-crystals so common in rhyolites. Crystals of enstatite are very frequently found included by plagioclase.

Fig. 1. Plagioclase (P) with inlets filled with basic glass. E. E. Crystals of enstatite.
In a thin vein ($\frac{1}{10}$ in.) of glassy enstatite-basalt (olivine-norite glass). Coonoor. × 35.

Fig. 2. Plagioclase crystal (P) with inlets of the pilotaxitic matrix. From olivine-norite dyke 3 inches wide. Coonoor. × 80.

IV.—VARIATIONS IN STRUCTURE.

10. The variation in size of grain is strikingly shown by a comparison of sections taken from the centres of dykes varying in width from 10 feet down to $\frac{1}{10}$ inch. In a dyke 10 feet wide the felspars attain a length of 0·025 inch (Plate XII, fig. 1). A section taken from a dyke 2 feet thick shows the rock to be very fine-grained (fig. 2), whilst in a dyke only 4 inches thick the groundmass is quite pilotaxitic (fig. 3), and in a branch from this dyke, only one tenth of an inch thick, the phenocrysts of olivine, pyroxene and plagioclase are seen lying in a brown, glassy matrix (fig. 4). It is interesting to note that the zone of enstatite forming the olivine crystal "court" becomes more marked in the finer grained varieties; in the wide dykes the crystals of the groundmass are not much smaller than those of early formation; that is, the rock is more distinctly porphyritic in the narrower dykes which cooled more rapidly than the larger masses. In the plate (fig. 4) the junction of the glassy variety of the olivine norite with the pyroxene granulite into which it is intruded is shown in the left-hand lower part of the field. The olivines of this thin vein have been altered to green serpentine, but in all the other specimens they are absolutely fresh.

Report on some trial excavations *for* Corundum *near* Palakod, *Salem District*, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India* (with plate XIII).

INTRODUCTION.

1. My preliminary reports[1] on the corundum-bearing beds in the Salem and Coimbatore Districts having shown that a practical trial as to the richness and value of the deposits was advisable, it was decided, after consultation with the Government of Madras, that the executive part of the work should be carried out by the Public Works Department under the supervision of the Subdivisional Officer of the Public Works Department for the Tirupatur Circle, whilst the sites to be tested and the general conduct of the operations should be superintended by myself, with the help of a native assistant geologist, Mr. S. Sethurama Rau, B.A., who would personally and continuously watch the operations and carry out instructions furnished by me.

2. I chose first a site in some waste land near the village of Erranahalli, and about 2½ miles south-west-by-south of Palakod, the nearest large town. The position was one among a number of outcrops of the corundum-bearing band, now known as the Paparappatti band. This will in future be referred to as No. 1 working. As soon as the necessary formalities had been complied with and the preparations completed, experiments were started in November 1896 and continued until 15th March 1897.

3. Before going any further, it will be well to state what was already known concerning these corundum occurrences. On my first visiting them in 1894, the only information then available was that corundum occurred near Pennagaram in the Dharmapuri taluq, as shown by the presence of specimens in the Madras Museum, thus labelled, sent by the local authorities. Since then details were from time to time gathered by my survey, so that up to the time of the opening of the pits at working No. 1, the information stood as follows:—

(*a*) The actual matrix of the corundum in this band was known to be in the form of lenticles in a gneiss, among which biotite was prominent as the dark mineral. Such of these lenticles as had actually been seen *in situ* were, however, small, the largest being 3 feet by 1 foot.

(*b*) That larger lenticles occurred in the alluvium covered plain near Paparappatti and on the hillsides to the west, was however inferred from large blocks having been found in the surface debris.

(*c*) It was known from the presence of old shallow trenches and pits in the alluvium and surface rock that corundum had been dug at some previous time from this neighbourhood. Local information and the exposure of corundum for sale in the surrounding market towns, also made it certain that corundum was at that time being occasionally gathered.

(*d*) It was also evident that, in a general way, the strike of the rock bands containing the corundum was with the strike of the country, namely,

[1] Reports to the Government of Madras, the first of which was reprinted with slight alterations in Records, G. S., I., Vol. XXIX, pt. 2, 1896, pp. 43—46.

about north by east, and it was supposed from the slightly different character of some of the corundum occurrences and also from their position that more than one parallel band of the rock existed.

(*e*) The position of all the corundum occurrences was as indicated on the accompanying plan, from which it will be seen that the Paparappatti band extends (but with some notable gaps) from Donnakuttahalli near the Cauvery river to Chintalakuttai village near Rayakottai, a distance of nearly 40 miles.

4. The general object of the practical work which I was now endeavouring to carry out was, as stated in the Annual Report of the Geological Survey for 1896, namely,—"The excavations, or quarries as they will be, are intended to show the thickness of the corundum-bearing bands, and whether they are continuous or occur as lenticular patches. A fair average sample of the rock extracted, of sufficient size to give a trustworthy estimate of the richness of the rock, is to be carefully cleaned by hand, and the proportion of corundum to matrix determined by weighing."

5. The nature of the work resolved itself into:—

(*a*) Preliminary clearing of the ground of jungle.
(*b*) Digging of trenches until the corundum-bearing rock was exposed.
(*c*) Blasting and quarrying the matrix-rock.
(*d*) Breaking up the lumps with wedges and hammers into sizes suitable for demolition by hand.
(*e*) Cleaning the corundum by hand and weighing.
(*f*) Excavations to show continuity or otherwise of the rock matrix.

GEOLOGICAL DETAILS.

6. A brief outline only will here be given regarding the petrology of the neighbourhood of the workings, inasmuch as many details still require working out. I may mention, however, in particular that in addition to biotite in the fundamental rock in which the lenticles occur there is at this place much hypersthene also present, which together with felspar, quartz and iron ores makes up a biotite-hypersthene granulitic gneiss, and which is therefore mineralogically a passage between the ordinary charnockite series and the Hosur biotite gneiss. It is finely, and not very distinctly foliated, the strike being generally between north and south and north-north-east and south-south-west. The dip of the foliation planes is generally steep, approaching the vertical in most available sections, but the amount and nature of the folds indicated by such dips are never definite enough to allow of a sectional representation of them.

7. Occurring sparingly as adventitious veins and veinlets in this gneissic rock and palpably younger in age than it, come a coarse flesh-pink and white, rather coarse pegmatite, and some trap dykes. These veins and dykes, though sometimes following the foliation, also occur completely irregularly. Some of the gneiss also presents the character which has been called "trap-shotten," a feature peculiar in itself and too complicated to be described in this note.

8. The actual matrix of the corundum in the workings was found, as anticipated from my previous observations, to be in the form of lenticles in the gneissic rock. These lenticles are symmetrically shaped and are easily recognised by their exter-

nal shell of rock very rich in biotite, and by the paler coloured central parts which are less rich in ferro-magnesian minerals. The exact mineralogical composition of these lenticles is still under investigation, and both it and the origin of the lenticles offer problems whose solution will not be attempted here. In size the lenticles vary from the very small ones referred to in my previous report up to such as the one broken up at No. 1 working, which measured 13 feet long, by 8 feet broad and 9 feet deep; the shape being that of an ellipsoid with three unequal axes. A plan showing the excavations at No. 1 working and in the vicinity (see Plate XIII) will sufficiently make clear the disposition, shape and size of the three lenticles which have so far been exposed in the course of the work, and will indicate the degree of probability attaching to the statement, which I think is a correct one, that these lenticles are really dispersed in a bed, layer, or plane, and that therefore they have the same general continuity as any other rock-band. In support of this it may be mentioned that half a mile west-south-west of Gollahalli subsequent trial trenches exposed a large lenticle, along the same line of strike, and identical in composition with the three already referred to. This lenticle on partial exposure measured 15 feet long by 8 feet broad.

As these lenticles were originally only indicated at the surface of the ground by the presence of fragments of corundum and matrix rock and by old shallow excavations, and as prospecting in the neighbourhood has revealed a great number of similar indications (roughly represented by the crosses on the map), it seems to me only reasonable to conclude that a detailed examination of the neighbourhood foot by foot, and a judicious series of cross trenches would expose more lenticles of the same kind along the present line or along other parallel lines. At the present moment there must be about 20 tons of matrix left at working No. 1, and about as much in the third lenticle, whilst the Gollahalli lenticle will probably yield 60 tons or more; so that about 100 tons of matrix-rock are now ready to hand.

9. The corundum in the matrix-rock occurs in well shaped crystals which in this particular locality are of a dark purplish-grey colour. As described in my previous paper, they are surrounded by a pale pink shell of orthoclase from which they break out sharp and clean like a kernel from its shell. Their forms are elongated barrel-shaped combinations of the hexagonal prism and pyramid. The size of the crystals varies considerably, but may be said to be definitely limited in the following way. The largest crystal found in the broken-up lenticle was 7 inches × 2 inches, whilst the smallest sizes of which any account need be taken are $\frac{3}{8}$ inch × $\frac{1}{4}$ inch. An average size for the crystals in this lenticle, I should estimate at 2 inches × $\frac{3}{4}$ inch.

The corundum seems to be quite pure throughout the lenticle, but in the course of the excavation, Mr. Sethurama Rau found that a layer of the outer disintegrated rock near the upper side of the lenticle yielded a number of dark nearly black lumps or nodules of hercynite mixed with corundum. Sometimes a central core of corundum was surrounded by a shell of hercynite. The latter is in a crystalline-granular state, and has probably grown in a concretionary way round pieces of corundum as nuclei. Unfortunately none of these concretions were found actually in solid rock, but inasmuch as none are present in the main mass of the lenticle, it is probable that they came from the outer crust of it where ferro-magnesian minerals are more thickly grouped.

PROPORTION OF CORUNDUM IN THE ROCK.

10. One of the chief objects, or rather *the* chief object, of the practical investigation of these rocks, was to determine by careful weighings the proportion of corundum in the matrix-rock. To attain this end, the broken-up rock was weighed as it was given out to the coolies, and the resulting corundum was collected at the end of each day and also weighed. This was done every day and a regular account kept.

The total results as given me by Mr. T. Ramanujam Pillay, Subdivisional Officer, Public Works Department, in charge of the work are:—

722 cwts. of matrix-rock yielded 2,845℔ of corundum,

or 3·5 per cent. nearly.

This total is considerably lower than the percentage obtained from the weighing of the first ton of matrix, which gave, as quoted in the Annual Report:—

1 ton of matrix-rock yielded 150℔ of corundum,

or 6·7 per cent. nearly.

From enquiry, and a study of the daily returns of the weighings, the difference seems to be accounted for in the following two ways. In the first place, when the original big lenticle was blasted, a great many of the larger crystals of corundum broke away and fell out, and they were straightway included in the first weighings. Secondly, all parts of the lenticle were not equally rich, and the richer parts appear to have been selected first. As a third reason it is possible that a certain amount of pilfering may have taken place from the exposed heaps of matrix-rock as time went on. It seems safest to take the total percentage on the whole work as giving probably the nearest approach to a true average, because so long as hand-work alone is used in cleaning the corundum, if loss occurs either by pilfering or carelessness, such would also be likely to occur in actual mining operations.

COST OF THE OPERATIONS.

11. Although a small experiment carried on as this one has been is likely to be more expensive than one worked on a larger scale as a paying concern, yet I give below the actual costs as offering some evidence under this head.

The figures given first below apply to the work done to the first two lenticles of matrix-rock at working No. 1, which supplied all the rock broken up and weighed. These figures also were furnished me by the Subdivisional Officer:—

	R	a.	p.
Clearing ground of jungle, about	20	0	0
Earthwork at the quarry, digging trenches, etc.	71	5	0
Blasting	11	9	0
Breaking matrix-rock and sorting 722 cwts. @ R0-2-6 per cwt.	112	6	0
Cleaning the above @ R0-2-6 per cwt.	112	6	0
Sundries—boxes, bags, cartage	35	0	0
Erection of sheds for workmen	22	8	0
TOTAL	385	2	0

or R0-8-7 per cwt. of broken rock,

i.e., R0-8-7 per 3·9℔ of cleaned corundum.

Further, it was found that 1½ men at 3½ annas were able to break 1 cwt. of matrix-rock and clean corundum from it.

12. The cost of making other excavations, exposing other lenticles, trial trenches here and at Gollahalli and near Paparappatti was R354.

13. From the figures given in paragraph 11, it will be seen that the two items of greatest expense are those for breaking out and cleaning the corundum by hand, namely (R112-6-0) × 2. It is clear, therefore, that if the extraction of corundum is attempted on a large scale, the adoption of machinery for crushing and washing the corundum, as a substitute for hand-work, would be a desideratum.

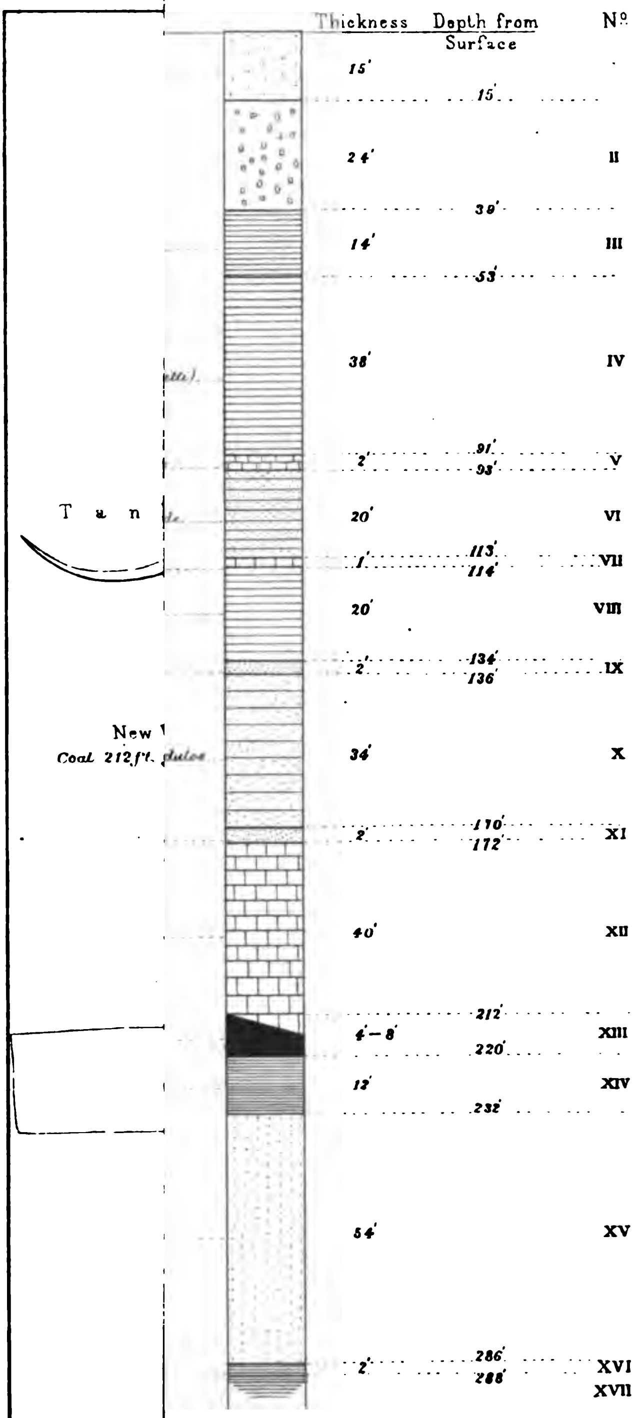
FURTHER EXPERIMENTS CONTEMPLATED.

14. Work for the present had to be closed on 15th March. Meanwhile samples of the corundum and matrix will be sent to firms in India and England for testing and valuation. Should their reports be favourable, and the percentage of mineral to matrix deemed not prohibitive, I shall hope to make further trial excavations at other places along the Paparappatti band of outcrops.

Report on the occurrence *of* Coal *at* Palana Village *in* Bikanir State *By* TOM D. LATOUCHE, B.A., *Superintendent, Geological Survey of India* (with plate XIV).

During the latter part of the year 1896, while sinking a well at the village of Palana in the State of Bikanir, a seam of coal was passed through at depth of 212 feet from the surface. A small sample of the coal was sent to the Geological Survey Office in Calcutta by Lieutenant-Colonel Vincent, Political Agent in Bikanir, for analysis, and the result, as given below, indicating that the coal was of fairly good qualtity, and would be of great value as fuel if it existed in any quantity, especially in a country so devoid of forests, where every ounce of coal for the railway has to be imported from a great distance and at enormous cost, it became of the highest importance to determine what steps should be taken to discover the extent of the seam. I was accordingly instructed to visit Palana before closing work for the season and report on this discovery.

The village of Palana is situated in N. Lat. 27° 51′ and E. Long. 73° 18′, about 13 miles to the south of the city of Bikanir. The country for several miles in every direction surrounding the village is entirely covered with blown sand and alluvium, no solid rock being anywhere visible at the surface. It is therefore only from the evidence afforded by wells that any information can be obtained about the rocks concealed beneath the surface. And not much can be learnt from the older wells, as their sides are covered with a hard cement to keep them from falling in. This new well at Palana was however sunk under efficient European supervision, and a record was kept of the strata passed through. I am indebted to Mr. J. E. Gabbett, Executive Engineer, Public Works Department,



L AT PALANA, BIKANIR STATE.

Scale 1in. = 40 ft.

the State Engineer, and to his Sub-Overseer Gunga Bishen, a most intelligent man, for the information embodied in the vertical section attached to this report.

The well is situated on the western side of the village (see plan), and at the time of writing is 288 feet deep. Water is expected to be met with at about 300 feet, which is the depth of the old well, said to have been sunk 14 generations ago, on the eastern side of the village, and about $\frac{1}{8}$ mile distant from the new one.

A glance at the vertical section will show that several of the beds, Nos. IV, V, VII, XII, passed through above the coal contain nummulites, and that a thick band of nummulitic limestone rests immediately upon the coal. Some distance below the latter there is a band of the unctuous clay called 'Multani Mitti' by the natives, which also belongs to the nummulitic series, so that the age of the coal is established as nummulitic or lower eocene. It may be mentioned that the coal of the Salt Range in the Punjab also belongs to this period, and occurs in a similar position beneath a thick band of nummulitic limestone. That the conditions necessary for the formation of coal seams were widely distributed in India at this period is proved by the fact that workable coal of the same age occurs not only in the Punjab, but also in Balúchistan, in Jammu territory, and to the east in Assam and Burma.

The coal as found in the well at Palana has a distinctly woody texture with a dark brown rather than black colour, and does not soil the fingers. In these characters it resembles the cretaceous coal of Assam rather than the nummulitic coals, and it also resembles the former in containing numerous specks and nests of fossil resin.[1] When exposed to the atmosphere it disintegrates rapidly, and becomes very friable, and is thus not well fitted for use in ordinary steam engines, as the small fragments and dust are liable to choke the boiler tubes. This difficulty can however be overcome, I believe, by the use of special methods of stoking. An analysis made in the Geological Survey Laboratory by Mr. Blyth gave the following result:—

Moisture	8·20
Volatile matter	42·72
Fixed carbon	39·28
Ash	9·60
	100·00

Sinters slightly, but does not cake.
Ash, light brown.
Calorific power in heat units (centigrade) 7,293.
Evaporative power, 13·58.

This indicates a fuel that will burn rapidly on account of the large amount of volatile matter, but will be somewhat deficient in heating power, owing to the comparatively small percentage of fixed carbon. The small percentage of ash is of course in its favour. The seam contains strings of iron pyrites but apparently not in large quantity, and the fragments can easily be picked out by hand.

In order to form an opinion as to the area over which the coal is likely to be found, we require to know first, whether the coal as found at Palana is a mere pocket, or whether it extends to any considerable distance from the well, and whether within that area it preserves a workable thickness, and secondly, what is

[1] Medlicott, Rec. G. S. I., Vol. I. p 13. The nummulitic coal of the Salt Range also contains specks of the same substance.

the extent of the formation in which it occurs, in order that we may determine in what direction further search should be made either by boring or well-sinking. With regard to the first point, the evidence afforded by the Palana well is, it must be confessed, somewhat disappointing. The section shows that on one side of the well the thickness of the coal is 8 feet, while on the other at a distance of only 10 feet the thickness is reduced to one half of this. The presence immediately above the coal of a thick band of limestone makes it appear very probable that this irregularity is due to erosion of the coal seam, during the changes of level that must have taken place between the period of growth of the vegetation that formed the coal, and the period of formation of the limestone, a marine deposit. Whether this erosion was merely local or whether it swept away the coal over a large area can only be determined by actual excavation. I had some cuttings made in the mound of sand and debris surrounding the old well at Palana, in the hope of finding whether coal had been passed through when that well was sunk, but with negative results, for though some dark-coloured patches were found, no fragments of coal were discovered. This is not surprising however when we consider that during the lapse of so many hundred years any coal that may have been brought up must have become entirely disintegrated, and would have been carried away long ago by the violent winds so frequent in the desert.

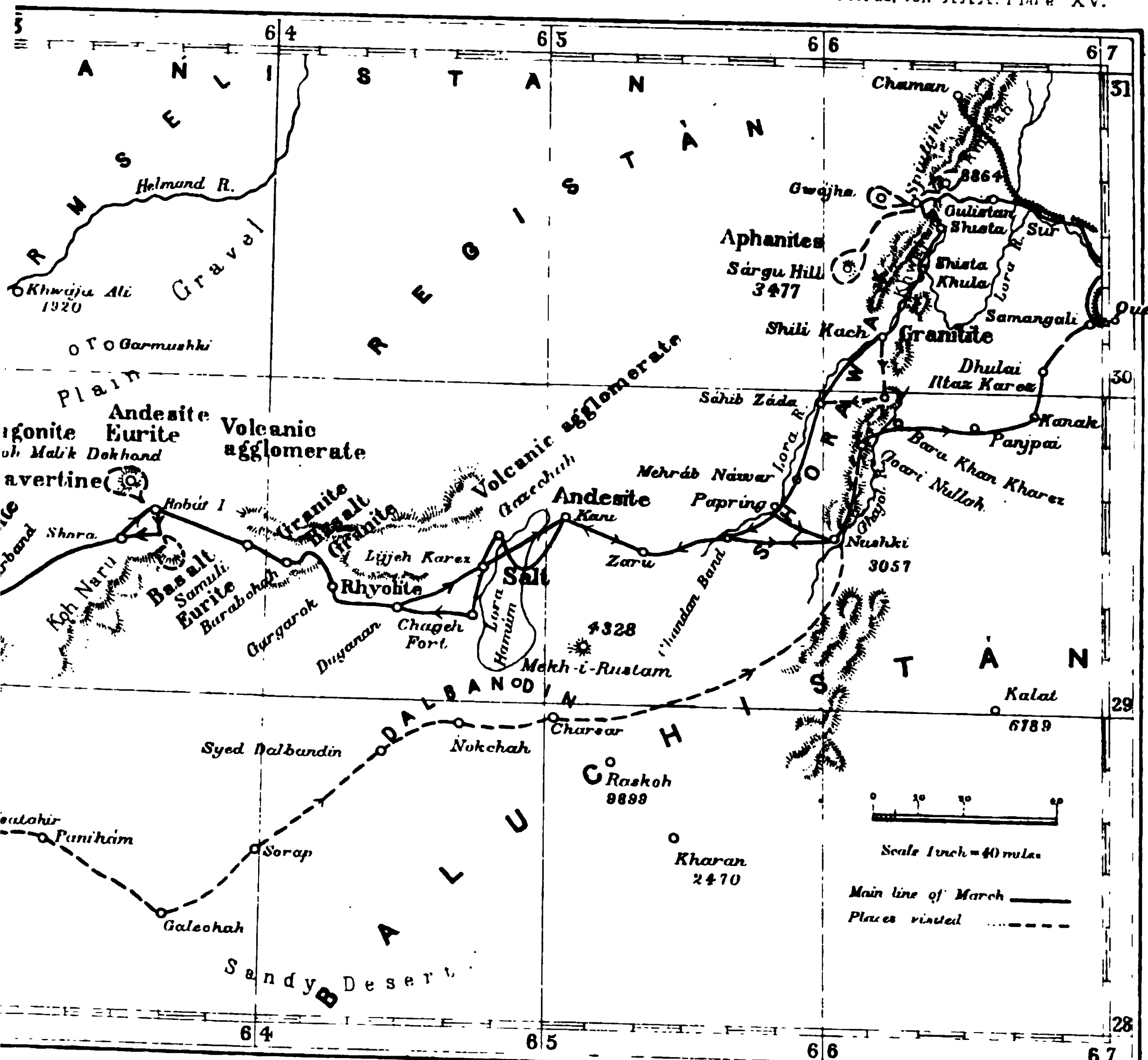
As to the second point, the extent of the formation in which the coal occurs, the information at our disposal is at present very meagre. As mentioned above, no rock is seen at the surface for many miles round Palana. To the west the nearest rock seen is in an elevated ridge, running from near Kolaith, about 20 miles due west of Palana, towards Bikanir. This is mainly composed of sandstones, which are of greater age than the nummulitics, but at the southern end near the village of Mar there are some quarries of the clay known as 'Multani Mitti.' There are several bands of this substance in the Palana well, but those above the coal, Nos. IV and VIII in the section are much inferior in quality to the Mar rock, and the only band to be compared with it is No. XVI which occurs at 66 feet below the coal. Moreover, no limestone or coal is seen below the clays at Mar and it is therefore probable that these are the outcrop of beds below the coal horizon, and that the outcrop of the coal would occur more to the east, in the sandy country between Palana and Kolaith.

To the east and south of Palana again no rock is seen at the surface, but in a well at Surpura, the second station south from Bikanir on the railway, at a depth of 120 feet from the surface, a band of white clay was passed through which closely resembles the band No. III in the Palana well, at 39 feet from the surface. This band in the Surpura well is 50 feet thick, and if these are portions of the same band the coal horizon should occur at a depth of about 330 feet in the Surpura well, of some 40 feet below the depth to which the well has been sunk. A boring carried down from the bottom of the well would soon decide this point, and in case limestone is met with before coal is found, should certainly be carried down to the base of the limestone.

As regards the steps to be taken in order to prove the extent of the seam discovered at Palana, I recommend that headings should be driven from the sides of the well in four directions at right angles to each other through the coal itself. The limestone above the coal should make a fairly sound 'roof' to the workings,

ICAL SURVEY OF INDIA.

Records, Vol: XXX. Plate XV.



SED BY THE BALUCH-AFGHAN BOUNDARY COMMISSION OF 1896.

so that it should hardly be necessary to timber them, if they were not wider than 4 feet. The coal extracted, supposing it to be continuous as far as the headings are carried, with an average thickness of 6 feet, would more than pay the cost of driving the headings.[1] Afterwards, supposing that a sufficient amount of coal is proved to make it worth while to start mining on a large scale, the colliery should be laid out and superintended by a properly qualified miner. When the existence or absence of coal has been proved to as great a distance from the well as can be reached by headings, borings might be put down in the surrounding country. But at present, until the conditions under which the coal occurs at Palana have been ascertained, it would hardly be advisable to incur the great expense entailed by borings with so doubtful a prospect of receiving any adequate return for the expenditure.

In conclusion, it may be well to mention that the occurrence of this coal at Palana has no bearing whatever on the question of the existence of the Gondwana coal measures in the desert of Western Rajputana; a question fully discussed by Mr. Oldham in 1886.[2] The Palana coal belongs to an entirely different and much later period of coal formation, and the existence of the Gondwana coal measures in this region still remains an open question.

An Account *of the* Geological specimens collected *by the* Afghán-Balúch Boundary Commission *of* 1896. *By* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India* (with plate XV.)[3]

I.—INTRODUCTION.

The geological specimens collected by Dr. F. P. Maynard and the other members of the Afghán-Balúch Boundary Commission can mostly be matched by the

[1] If the dimensions of the heading are 6 × 4 feet, the yield of coal for every 100 feet driven would be 80 tons. This could be raised and delivered on the railway, about 10 miles distant, for certainly less than R10 per ton, and as the present cost of imported coal is R30 per ton, the saving on every ton delivered would be very large, even allowing for a considerable difference in heating power.

[2] Records, XIX. 122.

[3] This paper was read before the Asiatic Society of Bengal in December 1896, and is printed here as it is considered more convenient that it should be published in the Records of the Geological Survey than in the Journal of the Asiatic Society. At the time it was written the specimens described were believed to be the only ones brought back from the Boundary Commission, but a paper read by Lieutenant-General C. A. MacMahon to the Geological Society of London on 24th March 1897 shows that this was not the case. Although it would have been more convenient for the whole of the specimens to be described by one individual, the incompleteness necessarily consequent on the absence of the specimens described by Lieutenant-General C.A. MacMahon does not seem sufficient reason for not publishing Mr. Holland's observations on these rocks collected from a region of which so little is known. The description of the physical features of the route is omitted as it will be found in Captain McMahon's contributions to the Geological and Royal Geographical Societies in London during the present year. *Ed.*

rocks obtained by the officers of the Geological Survey of India who have worked over a portion of the country crossed by the Boundary Commission, and on adjoining areas in both Balúchistán and Afghánistán.

Many of the specimens were evidently detached from their original beds and have suffered the usual results of exposure to weather. As it seems likely from the nature of the country that the specimens have not been far removed from their original positions, a brief record of their petrological character will be useful to future travellers who may have opportunities of supplementing the work of the Commission by tracing the rocks to their places *in situ*, and so obtaining the data necessary for an investigation of their geological relations.

II.—PETROLOGICAL CHARACTERS OF THE SPECIMENS.

The rocks collected are principally of igneous origin, the majority being either the direct or the secondary results of volcanic action. Those obtained in the eastern half of the route followed by the Commission are principally acid rocks, granites, eurites and rhyolites; whilst those collected further west—west of Robat I—are mostly diorites and andesites with their corresponding volcanic agglomerates.

A.—PLUTONIC ROCKS.

GRANITITE.—Specimens of granitite obtained from the Khwája Amrán range resemble those previously collected by Mr. C. L. Griesbach and Lala Kishen Singh of the Geological Survey of India. The specimens obtained from a peak near Shili Kach (Lat. 30°10′; Long. 66°13′) were biotite-hornblende granitites. Under the microscope they show signs of crushing, the felspars being frequently broken and the quartzes giving undulose extinctions. Plagioclase is the predominating felspar. Green hornblende and brown biotite are the only ferromagnesian silicates. Sphene occurs in large crystals; small granules of zircon and lumps of magnetite are common. The felspars frequently form micrographic intergrowths with quartz. The rocks show signs of slight decomposition, with kaolinization of the felspars, formation of epidote and loss of pleochroism in the hornblende and biotite.

GRANITITE-EURITE.—On the Koh-malik-do-khand (Lat. 29°40′; Long. 63° 33′) rocks occur of the composition of granitites and with the structure of eurites. The specimens collected, however, though containing an abundance of plagioclase felspar, are poor in ferromagnesian silicates. In some specimens porphyritic plagioclase crystals are the most prominent constituents, associated with a pale enstatite, and a few flakes of biotite, granular patches of magnetite are probably the result of fusion of a previous hornblende. Magnetite occurs also in larger lumps. The groundmass shows a fluidal arrangement of the microlites of felspar and probably granules of quartz.

Some of the specimens are encrusted with a white, radiating zeolite which exfoliates before the blowpipe and fuses to a vesicular glass. It has a hardness of 4·5 and a specific gravity of 2·21.

Eurites with much plagioclase felspar occur also on the hills south and west of Barábcháh (Lat. 29°25′; Long. 64°5′).

DIORITE:—*Quartz-diorite.*—Some of the specimens grouped with the diorites

approach the granites in composition, whilst others, in which quartz is wanting, are evidently more basic. An example of a quartz-diorite (quartz-hornblende diorite) was obtained near pillar No. 186 on the Koh-i-malik Siah range, at the western extremity of the line of march (Lat. 29°50′; Long. 60°55′). The rock showed a very distinct flow structure, and, from the description of its mode of occurrence, probably occurred as a dyke.

Mica-augite diorite.—More basic diorites occur associated with the quartz-diorite of the Koh-i-malik Siah range. In one of the specimens biotite, developed ophiticaly around its associates, stretches across large areas and produced a well marked lustre-mottling in hand specimen. Augite occurs in colourless crystals frequently twinned. These two minerals form a large proportion of the rock. Zoned granules of plagioclase form the matrix of the rock, in which grains of magnetite are plentiful, whilst apatite, sphene and zircon are rare. Calcite occurs as a secondary product of decomposition.

Aphanite?—An altered form of a rock probably related to this group occurs in the Sargu hill, cropping up in the plain west of the Khwája Amrán (Lat. 30°23′; Long. 66°12′). The rock has a fine grained matrix in which there are large quantities of black, opaque granules mixed with numerous crystals of plagioclase approaching oligoclase in composition. The black granules are probably the result of the reheating of the rock by some subsequent intrusion with the usual destruction of hornblende microlites. Amongst the glomero-porphyritic groups occur crystals having the shape and fracture of olivine, but their internal structure has been altered beyond recognition. Basic and ultra-basic igneous rocks have been found by Mr. Griesbach associated with the granitites of the Khwája Amrán, and it is likely that the specimens collected by the Boundary Commission are only altered forms of better preserved types in the Survey Collection.

B.—VOLCANIC ROCKS.

RHYOLITE.—The volcanic rocks containing silica as free quartz are apparently the true representatives of the granitites of the same area, containing always a marked quantity of plagioclase felspar and having the same ferromagnesian silicate, biotite predominating. Specimens containing good examples of bi-pyramidal quartz crystals corroded by the magma were collected at the crest of the Shibian pass (4,000 feet), in the hills north of Chageh (Lat. 29°17′; Long. 64°45′).

ANDESITE.—Andesites are by far the most numerous amongst the specimens of volcanic rocks collected by the Boundary Commission. They usually contain hornblende in some form as the ferro-magnesian silicate, and generally resemble the andesites in the Survey collection obtained by Surgeon-Major Brazier-Creagh, from South-East Persia.[1] The characters of the rocks collected over the western part of the route followed by the Commission are so strikingly like those of South-east Persia that there seems little doubt about their being part of the result of the same geological disturbance, of which the hot sulphur springs still left represent the final stages of a dying volcanic outburst.

The most interesting example of this group contains the comparatively rare soda amphibole, arfvedsonite, as its only ferromagnesian silicate. The rock has a rusted vesicular groundmass, with the cavities partially filled in with chalcedony.

[1] See pt. IV of this volume.

The large phenocrysts of plagioclase are strikingly zoned by inclusions of the glassy matrix. The crystals of arfvedsonite show the usual outlines and cleavage of amphibole, with a well marked pleochroism of—

$\mathfrak{a}$ = light greenish yellow.
$\mathfrak{b}$ = yellow.
$\mathfrak{c}$ = deep sherry red.

Extinction angle 5°, $c \wedge \mathfrak{c}$. The crystals are easily fused before the blowpipe. Specimens of this rock were collected near the Koh-malik-do-khand (Lat. 29°40′; Long. 63°30′).

Hornblende-andesites were also obtained in the same area on the hills south of Robat I, and, like nearly all the andesites, show the opaque granular resorption borders so frequently displayed by the hornblendes in rocks of this class.

Andesites were also obtained near Kani (Lat. 29°35′; Long. 65°5′); Gharibo hill, north of Dárband (Lat. 29°17′; Long. 63°); Amír-cháh (Lat. 29°16′; Long. 62°32′) and at Saindak (Lat. 29°20′; Long. 61°40′).

Nearly all the andesites show signs of decomposition and are impregnated with carbonate of lime.

BASALT.—Porphyritic, amygdaloidal, basic rocks occur near boundary pillar No. 165, west of Samuli (Lat. 29° 27′; Long. 63° 56′) the rocks are highly decomposed, and, besides relics of plagioclase phenocrysts, contain remains of what were probably olivine crystals, now completely devoid of original material.

A basalt dyke four feet wide was observed in the granite crossing the boundary into the Afghán territory near Barabchah (Lat. 29°26′; Long. 64°5′).

VARIOUS VOLCANIC PRODUCTS.—*Pumice* was picked up in a river bed, 6 miles east by north of Amír Cháh (Lat. 29°17′; Long. 62°34′) and was probably derived from an extinct volcano south by east of the place. The specimens contain occasional fragments of felspar crystals; the vesicles are drawn out into bands and are thoroughly impregnated with carbonate of lime.

Volcanic agglomerates, composed generally of rocks related to the andesites and basalts, were found at various places; for example, at Kambar Koh, a hill west of the Sarlat range; at Gazechah (lat. 29°32′; long. 64° 50′); on the Koh-malik-do-khand, containing fragments of augite andesite with a ferruginous cement, and, like all the other volcanic agglomerates, considerably decomposed.

Highly baked volcanic ashes were obtained in the Gharibo hill near Dárband.

Amongst the volcanic products also should be mentioned the *sulphur*, *selenite* and *galena* which occur near Saindak, which has already been referred to as the locality from which specimens of andesite were obtained. A peculiar soft ferruginous lithomarge, known as *mak* or *giri*, is obtained from the same place, and is collected and carried to Kandahar for dyeing purposes by *kakars* and *babars*. *Sulphur* and *alunogen* were also obtained in the Koh-i-Sultan.

The most interesting amongst the materials indirectly connected with volcanic action are the *travertines* of the Koh-malik-do-khand, from which various andesites were obtained. The travertine forms horizontal strata three or four feet thick, resting on gravel and consisting partly of white, columnar aragonite and partly of a yellowish translucent calcite in alternating layers. The aragonite has a specific gravity of 2·92 and the calcite, 2·72. Such alternate layers of the dimorphous carbonate of lime were probably the result of formation from water at different

temperatures. This is the substance evidently referred to by Dr. J. E. T. Aitchison in his "Notes on the Products of West Afghanistan and of North-East Persia" (*Trans. Ed. Bot. Soc.*, XVIII, reprint, p. 7), as limestone composed of layers of different colours together with alabaster and "chrysolite." In a note at the end of his paper Dr. Aitchison says the so-called "chrysolite" specimens were identified in Edinburgh as aragonite containing traces of strontia. I am indebted to Dr. Maynard for calling my attention to this note.

C.—Sedimentary Rocks.

The few specimens of sedimentary rocks collected by the Boundary Commission being without notes as to their stratigraphical relations deserve only a brief record of their characters. Shales, limestones, quartzites and conglomerates were brought from the neighbourhood of the Khwája Amrán. In the conglomerate the pebbles were slightly rounded and composed of quartz, quartzites and granitic rocks, the last sometimes showing most perfect micrographic structures. The quartzites and conglomerates are impregnated with infiltrated carbonate of lime. Coral limestones in rolled fragments were found at the foot of the Sarlat range, and on the east side of the gorge at Amír Cháh.

D.—Economic Minerals.

Near Kartárkar, Kacha Koh, and Saindak which are evidently close to the site of a dying volcanic centre, specimens of excellent transparent selenite, native sulphur and galena were obtained. Sulphur and alumstone were also obtained in the Koh-i-Sultan near the site of an extinct or dying volcano. The soft ferruginous lithomarge, known as *mak* or *giri* and used for dyeing, occurs in the hills south of Saindak and in the Koh-i-Sultan.

The remains of extensive copper smelting works were discovered near Robat II (Lat. 29°49′; Long. 61°6′).

A large dried up salt marsh occurs near the northern end of Lora Hamun (Lat. 29°27′; Long 64°52′). The salt being in the vicinity of recently extinct volcanoes is probably of volcanic origin.

Limestone occurs at various places, and a yellow translucent calcite was found in the neighbourhood of the Koh-malik-do-khand.

Notes from the Geological Survey of India.

Dysluite from Madras.—A new mineral and a new locality for a rare mineral may be recorded. Dysluite, the zinc-iron-manganese variety of gahnite has been found in the corundum-bearing granite of Padiyur in Coimbatore, in veins with felspar, quartz and zircon.

Columbite from Hazaribagh.—A new locality for this mineral may be recorded, specimens from the Government forest of Koderma in Hazaribagh having been presented to the Museum by Mr. Gow Smith. The present specimens differ from those previously recorded from Nawadih (Rec. xxvii, p. 8) in having a considerably higher specific gravity, *viz.*, 6·19 as against 5·54.

EARTHQUAKE OF 12TH JUNE.

On the afternoon of the 12th June, at five o'clock in the afternoon, Calcutta was startled by a shock of earthquake such as it had never felt before; many houses were more or less injured, the steeples of two churches broken off, and hundreds of people rendered homeless. Soon, however, it became evident that other places had suffered far more severely than Calcutta. Railway and telegraphic communication was cut off and it was only as the days wore on and news tardily arrived from the north and from the east that we found ourselves faced with a cataclysm which rivaled the classic earthquake of Lisbon in violence and extent.

No sooner were we aware of the scale of the event we had to deal with than preparations were made for its thorough investigation. The immediate succession of the rainy season on the earthquake rendered it imperative that observation of its effects should be made with all possible promptitude, and every officer of the Geological Survey then in Calcutta was despatched to observe and investigate. At the same time orders had been issued by Government to the local authorities to report fully on the effects of the earthquake. All the telegraph offices throughout India were instructed to report the time at which it was felt, and similar information was called for from all the station masters on the lines of Railway within the area likely to be affected. Circulars have also been widely distributed and communicated to the press, which has readily assisted in the endeavour to collect information.

The replies to these circulars and the reports called for from Government officials are now pouring in at a rate which defies satisfactory analysis, but some of the main facts about the earthquake, which have been already established, may be noticed here.

The area over which the earthquake was felt is enormous. On the east it has been reported as felt from the furthest extreme of Assam, at Mogok, Magwe, and Akyab in Burma; on the south, at Masulipatam in Madras, and Ellichpur in Berar; from Surat, Ahmedabad, Mount Abu, Ajmere, Panipat and Simla on the west. On the north it was felt at Katmandu; at Gnatong on the frontier of Sikkim and Thibet, it was severe enough to overthrow some of the barrack chimneys, and it is reported to have been felt at Lhassa. Besides these observations which are free from doubt, the shock appears to have been just perceptible to a few people, particularly sensitive or specially favourably situated in Dharmsala, Madras and Pegu. Omitting these last, there remains the fact that the range of the shock was over 24 degrees of longitude and 16 degrees of latitude or an area of over 1,500 miles in length and 1,000 in width, or, say, 1,275,000 square miles in all.

The area over which the shock was destructive is also great; from Darjiling, Monghyr and Calcutta on the west, to Jorhat on the east, damage and occasional destruction was caused to buildings, but this destructive force reached its maximum in Shillong, Cherrapunji and Tura. In Shillong, it may be said almost without exaggeration, that not one stone has been left standing on another. All masonry buildings have been levelled to the ground, and this, not by overthrow, but by a shattering of the walls into fragments, on the top of which the roof subsided. The nature of the destruction will be best understood by a reference to Plate XVI, which gives a view of Government house after the earthquake, drawn from a

photograph taken by Mr. F. H. Smith, of the Geological Survey. The other drawing on the same plate shows the influence of construction; the central portion of the hotel was built of stone and has been shaken to the ground. The two ends, however, which were additions to the original building and built of a wooden framework filled with reeds plastered with mud, have stood though severely shaken.

At Shillong it is possible to form some idea of the violence of the shock. In 1882 a seismometer composed of a series of cylinders of various diameters was set up. The largest of these is 12" by 9" diameter, and the whole series was overthrown to the north-eastwards. According to Omori's formula a cylinder of these dimensions would be overthrown in a direction away from the origin of the shock, as these were, by a velocity of wave particle of 2 feet per second and if we take the period of vibration as 1 second which is about that of the more severe shocks in Japan, this would imply a range of motion of 7·4 inches. In other words, the violence of the shock at Shillong, while it lasted, was at least equal to a backward and forward shake of 7 inches repeated 60 times a minute. If the range of movement was less, the rate of shaking must have been greater; if the movement was slower, the range of motion must have been greater in the same proportion.

That few structures, except those most strongly braced together or possessed of a very great flexibility, could stand this is not difficult to understand, and the violence of the to and fro movement will perhaps be best appreciated from the fact that the very boundary pillars have been shaken to pieces and heaps of broken road metal by the roadside were scattered out in layers of a few inches deep.

Earth-fissures and sand-craters are reported throughout the alluvial plains from Purneah on the west, to Jorhat on the east. They are, as is well known, only superficial and secondary results of the earthquake wave, but afford, among other information, instances of the extraordinary manner in which observation may be influenced by imagination. Numerous accounts speak of a strong sulphurous smell of smoke issuing from the vents and of hot, even boiling hot, water being poured forth. More temperate accounts show that the sulphurous smell was that of decaying vegetable matter, that the smoke was dust, and that the heat of the water was no greater than was to be expected in the middle of June. Closely allied in origin to the sand vents was the filling up of all the drainage channels, tanks and wells over large areas. That this was not due merely to an outpouring of sand, but to an actual forcing up of the bottoms of the hollows is shown by the effect on bridges, whose piers have been forced bodily upwards, as is shown in Plate XVII, reproduced from one of the admirable series of photographs taken by Messrs. Kapp & Co. of Calcutta. The other figure on the same plate, reproduced from one of the same series of photographs, shows how the rails have been affected by the movement of the surface alluvium consequent on the shock.

The rate of transmission of the wave was very high, in fact it has been stated in newspapers, and frequently spoken of, as having been felt simultaneously throughout Northern and Eastern India. Such was not the case, however, though the time the wave took to travel from its origin to the furthest point at which it was sensible to unaided observation does not appear to have been more than 8 minutes. The very large number of time observations, of every degree of accuracy, which have been communicated, have not yet been discussed, and no definite statement can be made, but a few selected at random as apparently good give an average rate of

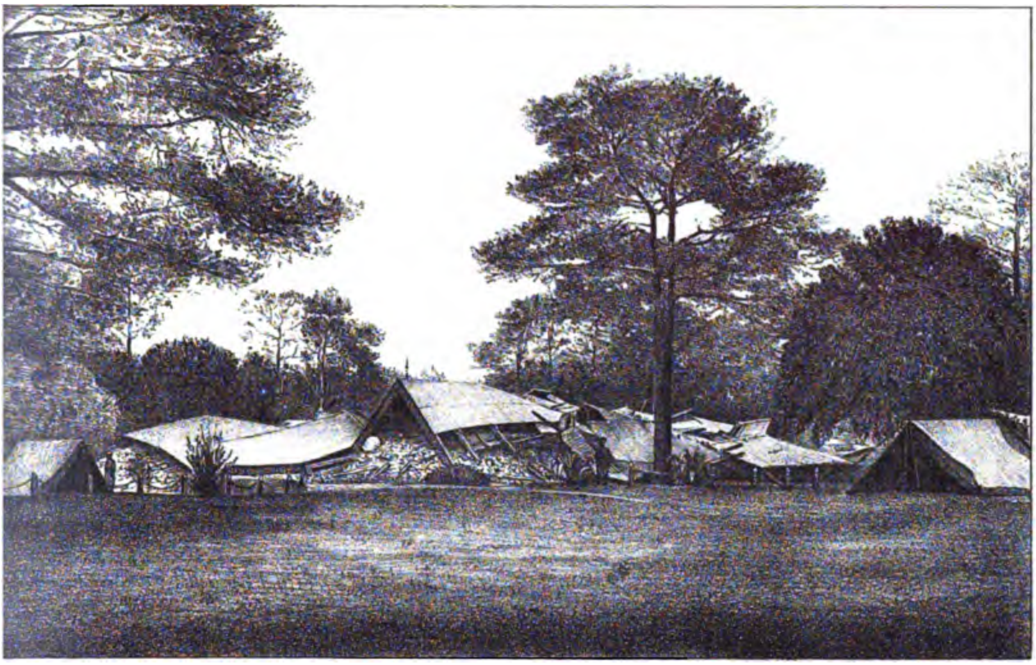
transmission of about 10,000 feet per second or over 112 miles per minute. This result indicates the order of magnitude of the figures we have to deal with, tho gh it cannot be accepted as final, or more than very approximate. The prevalent idea of the simultaneousness of the shock is disproved by a quaint report by the telegraph master of Chupra, who relates that he was working Durbhunga when there was suddenly a stoppage due to the earthquake at Durbhunga, and the signaller leaving the instrument there, and immediately afterwards the earthquake was felt by him. According to the daily papers a similar incident took place at Dhubri, which was at the time in communication with Goalpara.

Beyond the area over which the earthquake was felt its effects were traced instrumentally at Bombay, where the instruments in the magnetic observatory were affected by a disturbance commencing between four and five minutes past four, local time, or 16 h. 34 m. Madras time, that is, 6 minutes later than the shock was felt at Calcutta, and about 9 minutes after the probable time at which the shock started on its way from the place of origin, somewhere below the Garo or Khasia hills.

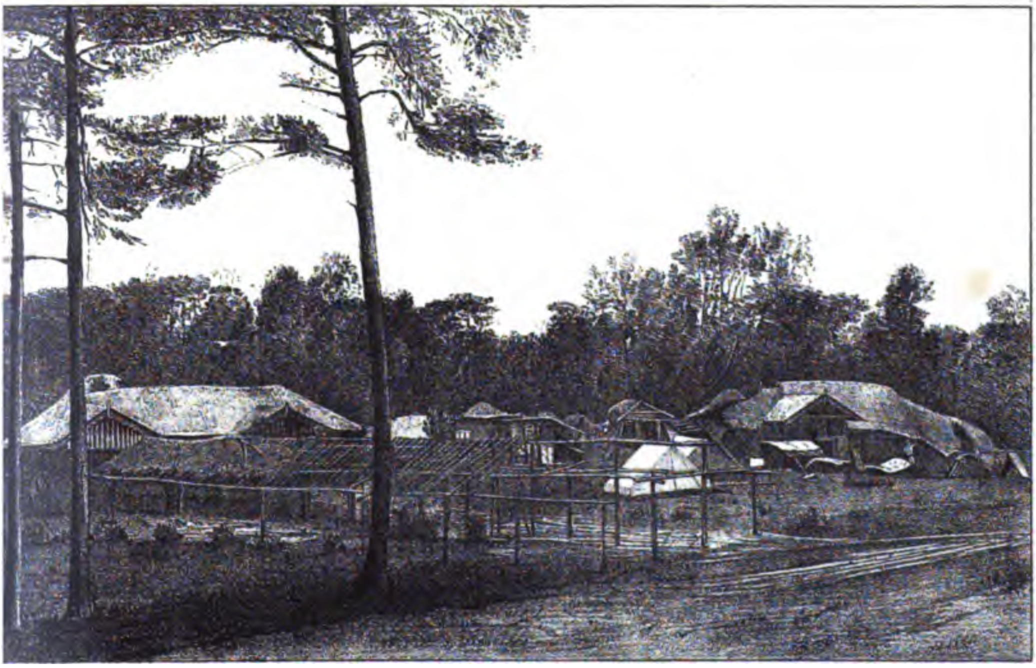
The effects of the shock are said to have been traced at Grenoble; and at Edinburgh a letter from Mr. Heath, Assistant Astronomer, to *Nature*, gives the time at which the tremors were first felt as June 11th, 23 h. 18 m. G. M. T.; they lasted about 10 minutes and then ceased, and violent oscillation again set in at 0 h. 32 m. G. M. T. of 13th June and continued up to 1 h. 12 m. They were equivalent to a tilting of the ground through 20 seconds of arc. Greenwich mean time June 11th, 23 h. 18 m. (astronomical) corresponds to Madras time 16 h. 39 m. of 12th June, (civil); 0 h. 32 m. G. M. T. of 13th June corresponds to Madras time 17 h. 53 m. of 12th June. If both these sets of tremors were due to the same earthquake the first must have travelled the distance from the origin to Edinburgh, starting at about 16 h. 25 m. Madras time, in 14 minutes, the other in 1 h. 28 m.

These few notes form no adequate account of the earthquake; this is in preparation, but the collection and discussion of the information will take some time. Meanwhile what has been written will serve to show the order of magnitude of the cataclysm of 12th June 1897, an earthquake unsurpassed by any since the great Lisbon earthquake of 1st November 1755, and rivalling this in magnitude of the area over which it was felt, surpassing it indeed if we exclude the doubtful records of the earlier shock.

31st July 1897. R. D. OLDHAM.

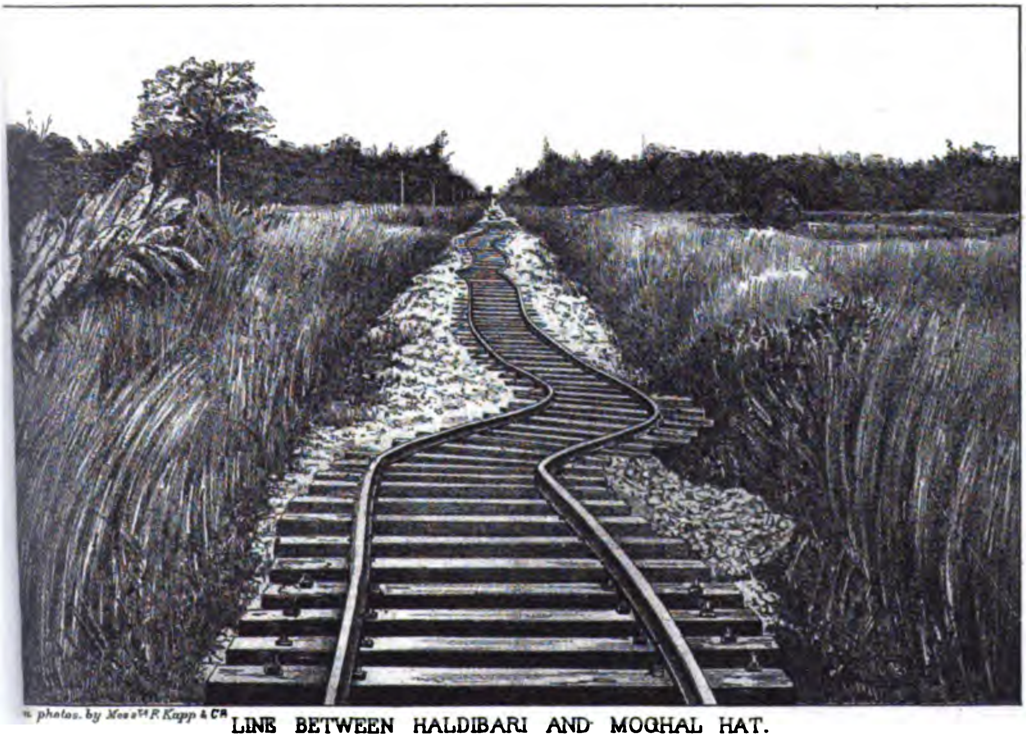


GOVERNMENT HOUSE SHILLONG.



FERNDALE HOTEL SHILLONG.

BRIDGE ACROSS NALLAH AT HALDIBARI.



photos. by Messrs F. Kapp & Co.

LINE BETWEEN HALDIBARI AND MOGHAL HAT.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4. 1897. November

ERRATA IN Vol. XXX, Pt. 3.

Page 134, lines 23 and 24 *for* "About 10 minutes and then ceased, and violent oscillation again set in at 0h. 32m. G. M. T. of 13th June and continued up to 1h, 12m." *read* "for 10 minutes when suddenly violent oscillation set in and lasted till 0h. 33m. G. M. T. of June 12th; giving place to slight tremors which continued till 1h. 12m."

Page 134, line 27, *for* "13th June" *read* "12th June."

but differed more or less in the amount of alteration they had undergone, which could be roughly judged by eye through variations in colour and translucency. The sample, I selected, was one of those which appeared to have undergone the least change.

It consists of a mass of straight, very fine, highly flexible and elastic, easily separable fibres eight inches long, which seem clearly to have formed part of a vein. Some particles of serpentine, adherent to one end of the specimen, indicate that the rock in which brucite has generally been found elsewhere is the probable matrix in Afghánistán also. The ends of the specimen show that the fibres were not perpendicular to the walls of the vein, as is more usually the case with fibrous minerals, but made an angle with the walls of about 20° (or 160°). Whether this was due to a local twist in the direction of the walls at the spot from

[1] Reprinted from the Mineralogical Magazine, Vol. X, No. 52, pp. 211—214.

which the specimen was taken, or is common to the whole vein, I do not know[1]. Both ends of the specimen show very obvious signs of chemical alteration, but the central part, for about five inches, is, to all outward appearance, both to the naked eye and under the microscope, perfectly fresh; and that it has not undergone any considerable change is shown by the absence of both carbonic acid and ferric oxide. The sample used for examination was of course taken from this central portion.

Transverse to the direction of the fibres the colour by reflected light is sea-green with a silky lustre: by transmitted light pale to dark sea-green according to the thickness of the specimen; the extreme red and the violet being the rays most strongly absorbed, together with the blue if the thickness be sufficiently great. Looked at by transmitted light parallel to the direction of the fibres, the colour is very similar. In a specimen an inch long the colour is sufficiently intensified to approach a pale emerald green. The colour of the mineral is doubtless due, mainly at least, to the unusually large amount of ferrous oxide it contains. Neither transverse nor parallel to the direction of the fibres is there any perceptible dichroism.

A section perpendicular to the direction of the fibres[2] shows no dark cross or rings in convergent polarised light; in parallel light with crossed nicols the field is rather brightly illuminated, and revolution of the nicols together does not alter the illumination. A cylinder of the fibres, again, lying parallel to the stage of the microscope, exhibits double refraction, and no alteration in the phenomenon is observable during a revolution of the cylinder on its own axis. The axis of greater optical elasticity is in the direction of the fibres. The above observations are in consonance with the statement of Lévy and Lacroix that in nemalite "les fibres sont allongées suivant un des côtés de l'hexagone et négatives,"[3] and with the optically positive character of brucite, nemalite included. But they apparently indicate that the vertical crystallographic axes, *c*, in the different fibres (which are so minute that in a cross section they are individually quite invisible under the microscope[4]), lie, not in parallelism with each other, but in varying directions in the plane perpendicular to the cross section of the fibres.

The value obtained for the specific gravity, at 60° F. is 2·454; a high result which must be ascribed to the large amount of iron present.

The mineral gave on analysis (free from hygroscopic moisture):—

		Oxygen ratio.[5]
Magnesia	62·00	24·58 } 26·33 = 1·003
Ferrous oxide	7·87	1·75 }
Manganous oxide	tr.	
Water	29·55	26·24 = 1
Silica	·38	
	99·80	

A faint trace of lime was detected spectroscopically.

[1] Prof. Hidden, who was present when this paper was read, remarked that in the nemalite of Hoboken, New Jersey, there is a similar obliquity between the direction of the fibres and that of the walls of the vein.

[2] I am indebted to Professor J. W. Judd, C.B., for kindly having the section cut for me, and also for several references bearing on the subject of brucite.

[3] *Les Minéraux des Roches, 1888*, p. 612.

[4] With linear magnification of 180.

[5] Mg = 24 36, Fe = 56·0, H = 1·0076.

The only point in which the above figures differ noticeably from Mr. Blyth's is in the smaller amount of iron. But the portion used in his analysis was from a different specimen, obtained at a different time, and possibly from a different part of the vein; and more or less variance in the relative proportions of the isomorphous oxides is what might be expected.

The silica is left undissolved by hydrochloric acid in the form of translucent tangled fibres, which dissolve in a hot solution of sodium carbonate. They are indistinguishable in appearance from the silicious fibres which remain when chrysotile is decomposed by the same reagent. As nemalite and chrysotile are both usually found under similar conditions—in the form of veins traversing serpentine—it seems not unnatural that the two allied magnesian fibrous minerals should coexist, intimately mixed, in the same vein, and it appears not improbable that such is the case in the substance under discussion.

If, then, the silica be regarded as a constituent of chrysotile, and to the latter be assigned the theoretical composition of the mineral, with the magnesia and iron in the same proportions, relatively to each other, as in the nemalite, the above analysis will stand as follows:—

	Chrysotile.	Nemalite.	Calculated to 100.	Oxygen ratio.
Magnesia . .	·35	61·65	62·32	24·71 } 26·47 = 1·001
Ferrous oxide .	·04	7·83	7·92	1·76 }
Manganous oxide .	...	tr.	tr.	
Water . .	·11	29·44	29·76	26·43 = 1
Silica . .	·38			
	·88	98·92	100·00	
	$\underbrace{\text{·88 + 98·92}}_{99·80}$			

Granting the existence of the chrysotile, whether it should be regarded as formed synchronously with the nemalite, or as present owing to one mineral having been altered into the other, I do not know. As previously remarked, the substance analysed showed no indication of change, unless the presence of silica be regarded as such. On the other hand, a portion of the substance near the end of the specimen, where it was obviously changed, contained 2·26 per cent. of silica fibres = 5·28 per cent. of chrysotile, or six times as much as the portion analysed. But this excess of silica was accompanied by the presence of carbonic acid and ferric oxide, which might therefore perhaps be expected to accompany the smaller amount of silica (·38 per cent.) also, if the latter were due to alteration of the nemalite; and the large percentage of silica may be caused merely by original unequal distribution of chrysotile through the specimen.

Near the ends of the specimen the original green colour is changed to a light hair-brown, the mineral still retaining its translucency, the alteration being due to a very partial peroxidation of the iron. Beyond that again the fibres are white, with a pale reddish tinge, and comparatively opaque. These (besides the silica mentioned above) contain a considerable quantity of carbonic acid, owing to the nemalite having been more or less fully converted into hydromagnesite; and the ferrous is largely, or entirely, changed to ferric oxide. There is also a certain amount of non-fibrous, and scaly, or in part stellate-lamellar hydromagnesite on the ends of the specimen, formed, apparently, by deposition on the nemalite, not

by alteration *in situ*. This hydromagnesite encloses some magnetite, which may perhaps be taken as representing part of the ferrous oxide of the nemalite (from some other portion of the vein), from which the deposited hydromagnesite was probably formed.

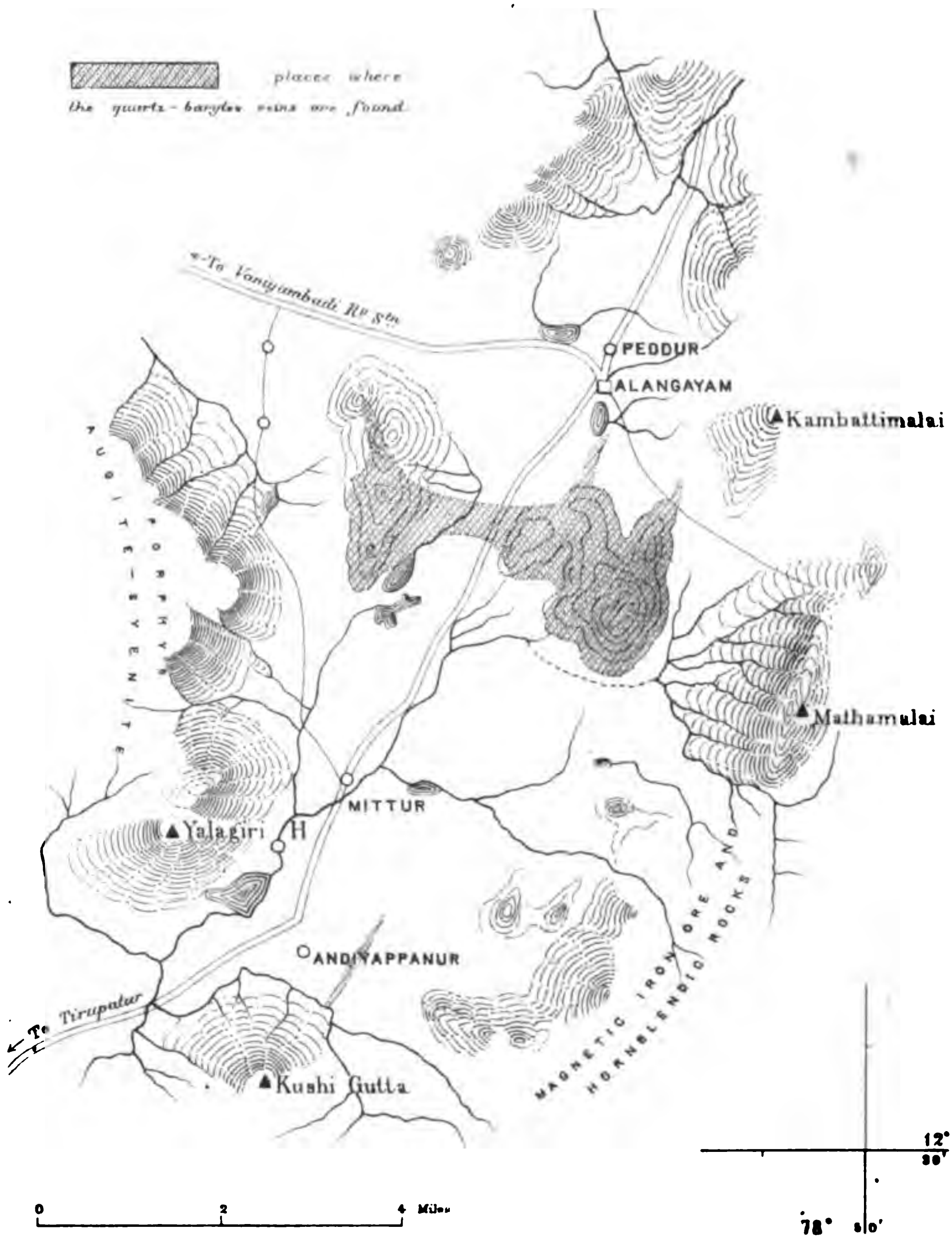
Fibres of the nemalite held in the zone of fusion of a Bunsen burner, shine with the rather high luminescence of ignited magnesia. As they possess considerable tenacity, as well as much flexibility, there is little doubt that it would be possible to weave some kind of fabric from them, which might be used for incandescent mantles. But in face of the superior luminosity of the materials already employed, and the easier process of manufacture, there is little reason to anticipate that such an application of the nemalite would be commercially profitable. And, further, even were the use alluded to more promising, nothing is known at present as to the quantity in which the mineral could be obtained.

On a Quartz-barytes rock *occurring in the* Salem district, Madras Presidency. *By* T. H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India* (with Plate XVIII).

When barytes occurs as one of the "spars" of compound mineral lodes, such, for instance, as its common occurrence in galena lodes, the constituent minerals generally present the "banded" and "comby" structure which is supposed to be the result of successive deposition of minerals in a gradually widening fissure. The same mineral also occurs infilling cavities in amygdaloidal traps, cavities in fossils, fissures in limestones or sandstones, and often also as a cement binding together the sand-grains in the latter rock—occurrences which suggest a secondary origin for the mineral, and also point to its deposition by precipitation from aqueous solutions. The concretionary nodules found in some clays, and amongst the deep-sea deposits, are also formed by the chemical precipitation of barium sulphate from solution in water.

2. But the occurrence of this mineral with quartz, forming a network of veins, such as have recently been discovered in the Salem district, appears to be unique in character, and can hardly be explained by the theory applied to the commoner occurrence of barytes in mineral lodes. About midway between Mittur and Alangayam (lat. 12°38′; long. 78°47′) in the Tirupatur taluk, Salem district, two low hills are found to be formed largely, and as far as could be seen in the southern part of the western hill entirely, of a rock composed of quartz and barytes, whilst numerous veins of the same material are found penetrating the crystalline rocks in the neighbourhood.[1] These veins are found stretching as far

[1] The valley in which the town of Alangayam lies separates the Yelagiri Hills, composed principally of a porphyritic augite syenite, from the Javadi Hills, composed of gneissose rocks with which beds of magnetic iron ore are found associated.



DISTRIBUTION OF THE QUARTZ-BARYTES ROCK NEAR ALANGAYAM.

as Alangayam, a distance of two miles north of the main plexus, and as far as Andiyappanur, a distance of five miles southwards; but in the latter instance the outcrop is only traceable for a distance of half-a-mile in a N.E.—S.W. direction on the south-eastern side of the village of Andiyappanur; but as the main mass of the rock lies to the north-east of Andiyappanur, that is, the direction of the outcrop of the vein, it is more than probable that this vein is merely an offshoot from the main mass south-west of Alangayam, its outcrop being covered by the cultivated alluvium which extends over the intermediate area.

3. The prevailing rock of the area, through which the quartz-barytes rock is injected as veins, is a pyroxenic gneiss, presenting a mottled appearance in hand-specimens, and showing under the microscope a considerable advance towards the change of the pyroxene into amphibole. But in addition to the gneiss, veins of the quartz-barytes rock are found crossing dykes of microgranitic rocks, which, though intruded before the injection of the quartz-barytes rock, must have been erupted subsequently to the foliation of the gneiss. Although the actual contact has not been observed, the quartz-barytes vein near Andiyappanur shows a continuous outcrop across, and at right angles to, a very thick dyke of augite-diorite, similar to the common trap-dykes which in South India are generally regarded as the representatives of the Cuddapah lava-flows (*Rec. G. S. I.*, Vol. XXX, p. 16). It is probable, therefore, that the quartz-barytes rock is younger than this trap.

4 The veins of quartz-barytes rock vary in thickness from mere strings to dyke-like masses several feet across, and the fissures which they occupy instead of lying within a few degrees of the vertical, as is commonly the case with undisturbed trap-dykes, are found with their flat surfaces lying at all angles to the horizon.

5. But the size of the veins seems to have no recognisable connection with the sizes of the crystals composing them; even in the thin strings the barytes forms large crystals, and on this account, as much as on account of the colour of the minerals, the rock presents a most remarkable resemblance to an acid pegmatite when first seen in the field. The barytes crystals are scattered through the quartz in a most irregular manner; there is no parallel disposition with regard to the sides of the vein, and no trace of the "comby" structure which so often characterizes mineral lodes. There is, in fact, no reason for supposing that the conditions under which this material was injected into the veins, were essentially different to those under which the material, when of a different chemical composition, crystallizes as a pegmatite. The distances to which some of the veins are found to extend, and their uniformity of composition throughout, show that the substance originally injected must have been in a fluid state. The idiomorphic outlines presented by the barytes, and the complete absence of any other mineral after which it might possibly be pseudomorphous, point to its occurrence as a primary constituent. We conclude, therefore, that, whatever may have been the conditions of temperature under which it was injected, this peculiar rock has been formed by the consolidation of a mobile magma from which quartz and barytes separated as the principal results of its primary crystallization.

6. The veins of this rock are made up principally of quartz and barytes, with which there occur very much smaller quantities of galena, pyrite, ilmenite

hematite and limonite, the last-named two minerals occurring with a dirty clay in the decomposed specimens.

To form an estimate of the relative proportions of quartz and barytes, the two main constituents, 60 specimens were determined by Mohr's specific gravity method by Mr. T. R. Blyth, under Mr. H. H. Hayden's superintendence. The results were as follows:—

	Number of pieces used.	Weight in grammes.	Water displaced in cubic centimetres.
A	1	2799·05	986·30
B	1	1851·10	446·15
C	1	1606·45	555·90
D	1	1650·59	515·54
E	1	1392·95	465·15
F	1	1156·45	341·30
G	25	884·01	261·00
H	6	605·79	227·00
I	4	815·05	299·00
J	3	964·99	317·00
K	2	529·09	189·00
L	2	633·28	235·00
M	2	733·21	234·00
N	2	581·31	202·00
O	1	475·18	180·00
P	1	671·85	245·00
Q	1	826·73	287·00
R	1	721·55	271·00
S	1	739·80	267·00
T	1	589·82	208·00
U	1	475·58	164·00
V	1	564·36	182·00
	TOTAL .	21268·29	7078·34

The average specific gravity of the rock is thus —

$$\frac{21268{\cdot}29}{7078{\cdot}34} = 3{\cdot}005$$

Knowing then the specific gravity of the rock to be 3·005, and that of its two

principal constituents to be 2·65 and 4·30 respectively, the percentage composition of the rock can be determined as follows :—

Taking x to be the percentage proportion of quartz, $(100-x)$ must be that of barytes, then—

$$3\cdot005=\frac{100}{\frac{x}{2\cdot65}+\frac{(100-x)}{4\cdot3}}$$

from which x is found to be 69·2. The percentage composition of the rock is thus—

Quartz	69·2
Barytes	30·8
	100·0

This result confirms our decision in rejecting the theory of pseudomorphism after felspar which was considered in paragraph 5; for the proportion of quartz to felspar in pegmatite, at least in the graphic varieties, is quite different (cf. Teall, British Petrography, p. 402).

In view of the presence of the accessory minerals mentioned in paragraph 16, a special test for gold was made by Mr. Blyth, with the result that 19 lbs. of the rock yielded gold in the proportion of 13 grains to the ton. Although this is of course well below a profitable minimum, the area seems quite worth further testing on a larger scale.

QUARTZ.

7. The natural colour of the quartz varies from white to grey—the colours of the common vein quartz frequently found in the neighbourhood of intrusive rocks. The true colour of the quartz is, however, generally masked by ferruginous stains produced be rusty infiltrations along the cracks, which are sufficiently numerous to render all specimens of the rock easily friable.

8. Microscopic sections show the quartz to be composed of an aggregate of irregularly interlocking crystals, which are very variable in size, sometimes an inch or two across, and at other times quite microscopic. The white and grey colours, as well as the imperfect transparency of the quartz, are evidently due to the innumerable microscopic cavities seen in section. These cavities are often arranged in bands, and are sometimes filled with liquids containing bubbles. In one specimen of quartz, which was distinctly blue in colour, small zircons and long, hair-like inclusions were abundant. The resemblance of this quartz to that which is found so abundantly in the charnockite series of the same district, suggests the foreign origin of this particular piece, although no further instances of included older rocks have been found.

BARYTES.

9. The barytes occurs as crystals often measuring 2 or 3 inches across, which generally form groups of several individuals. The junction surfaces between the barytes and the quartz often agree with crystal faces of the former mineral. Thus indicating that the period of crystallization of the barytes was on an average in advance of that of the quartz.

10. When transparent the colour of the crystals varies from grey to pink, and

in thin cleavage plates they are colourless; but most of the crystals are disfigured by irregular, cream-coloured patches which are nearly opaque. These patches give the crystals a remarkable resemblance to kaolinized orthoclase when first seen in the field. One specimen showed a zonal disposition of black inclusions.

11. The basal and the prismatic cleavages are perfectly displayed in every piece, whilst thin sections cut parallel to the basal plane show an additional, but noticeably less perfect, cleavage parallel to the brachypinacoid (010). Several determinations made on a basal section gave an average of 78° 30′ and 101°30′ as the angles between the prismatic cleavage cracks.

12. The perfect display of cleavage cracks facilitates the preparation of sections parallel to the pinacoidal faces for the purpose of examining the optical characters. Sections cut parallel to the macropinacoid (100), that is, at right angles to the basal plane and bisecting the acute angles of the prismatic cleavage cracks, show the biaxial figure in convergent polarised light, from which the positive character of the double refraction is easily proved, whilst the optic axial angle is seen to be small. The line joining the optic axes in these sections lies at right angles to the basal cleavage cracks, consequently the optic axial plane must be parallel to the brachypinacoid (010). The optical scheme is thus—

$$\begin{array}{ccc} a & = & \mathfrak{c} \\ b & = & \mathfrak{b} \\ c & = & \mathfrak{a} \end{array}$$

which is confirmed by using the quartz wedge on the basal and brachypinacoidal sections.

One of the most interesting features in connection with these sections is the remarkable difference between the colours displayed by the macropinacoidal and those shown by the other pinacoidal sections between crossed nicols. Thin sections cut parallel to the macropinacoid show extremely low colours, as low in fact as the grey, whilst sections of the same thickness cut parallel to the other pinacoids polarise with reds and blues of the first order. This interesting phenomenon is evidently due to the fact that there is a much smaller difference between the maximum and the mean than between the mean and the minimum coefficients of elasticity, or, which is the same thing, the refractive indices α and β approach one another very closely—a fact which finds expression in the narrowness of the optic axial angle. The values of the refractive indices for the D line given by Dana[1] after Arzruni are :—

$$\begin{array}{ccc} \alpha & = & 1{\cdot}63609 \\ \beta & = & 1{\cdot}63712 \\ \gamma & = & 1{\cdot}64795 \end{array}$$

We have therefore—

$$\beta - \alpha = {\cdot}00103;\quad \gamma - \beta = {\cdot}01083, \text{ and } \gamma - \alpha = {\cdot}01186$$

Whilst, therefore, the basal sections, containing γ and β, and the brachypinacoidal sections, containing γ and α, show comparatively high double refraction, higher indeed than that of quartz, the macropinacoidal sections, containing β and α, show a very low double refraction, lower even than that of apatite. As one result of this interesting circumstance the small granular crystals of barytes, frequently found filling in cleavage rifts in the larger individuals appear as a brightly polar-

[1] System of Mineralogy, 6th Ed., page 902.

ising mosaic, whilst the macropinacoidal section, forming the principal part of the field, exhibits low grey colours. Owing to the strain phenomena the character of the dispersion could not be made out with certainty; in fact, as a result of this strain the colour dispersion appears to be as often "crossed" as of the rhombic type.

13. The macropinacoidal sections often show a very imperfect lamellar twinning parallel to the brachydome (011). The traces of these twin-planes appear on the basal surfaces as very fine lines bisecting the obtuse angles of the rhombic cleavage cracks. As many of the crystals are noticeably bent, the twinning is probably secondary and due to pressure, as was shown by E. S. Dana[1] to be the case with the so-called michel-lévyte described by Lacroix, and in other instances by Max Bauer.

14. The cream-coloured patches already alluded to are less transparent under the microscope. Apparently the barytes has been altered along these areas and irregular cavities have been produced by removal of the material in solution. In the clear and unaltered parts of the crystals also there are bands of cavities with liquids containing bubbles; but these have a different origin.

15. The average specific gravity of the crystals is 4·30. Examination before the blowpipe gave the usual reactions for barytes, indicating the presence of barium by the apple-green flame and of sulphur by the sulphide stain on silver. Many of the specimens are distinctly fetid when rubbed. A chemical analysis, made by Mr. T. R. Blyth under the superintendence of Mr. H. H. Hayden, in the Geological Survey Laboratory, gave the following results:—

Moisture	0·04
Loss on ignition	0·26
Silica	0·63
Ferric oxide and alumina	0·93
Barium sulphate ($BaSO_4$)	94·15
Calcium sulphate ($CaSO_4$)	4·01
	100·02

The chemical analysis thus confirms the physical evidence as to the great preponderance of barium sulphate in these crystals, and the replacement of a small proportion of the barium sulphate by the isomorphous sulphate of lime accounts for the slightly low value of the determined specific gravity (4·30). Taking the specific gravity of pure barium sulphate (barytes) to be 4·40, and of pure sulphate of lime (anhydrite) to be 2·95, a mixture of the two compounds in the above proportions would have a specific gravity of—

$$\frac{26{\cdot}16}{94{\cdot}15 \div 4{\cdot}4 + 4{\cdot}01 \div 2{\cdot}95} = 4{\cdot}31$$

which closely agrees with the observed specific gravity of the crystals.

ACCESSORY MINERALS.

16. Compared with the quartz and barytes, the minerals galena, pyrite, ilmenite, hematite and limonite occur in extremely small quantities, and show a tendency to local concentration, with the result that, whilst nearly all these accessories are represented by small crystals in some specimens, in others they are entirely absent. Of

[1] *Amer. Journ. Sci.*, 3rd ser., Vol. XIX (1890), p. 61.

these accessory minerals galena appears to be the most widely distributed, pyrites occurring next in order of abundance. Both these minerals appear to be original constituents of the rock; but the limonite and hematite are more probably secondary, as they are found infilling cavities, which, from their shapes, were apparently formed by the removal of barytes in solution by secondary causes.

SUMMARY.

The rock described in this note is composed almost wholly of quartz and barytes in the proportion of 7 of the former to 3 parts of the latter mineral. A portion of the barium in the barytes has been replaced by lime; analysis of the crystals, which have a specific gravity of 4·30, showing 4·01 per cent· of lime sulphate. With the quartz and barytes occur very small quantities of galena, pyrite, ilmenite, hematite and limonite, the last two named being of secondary origin. An assay of the rock yielded 13 grains of gold per ton.

This rock forms a large plexus of veins cutting through the pyroxenic and other gneisses between Alangayam and Andiyappanur in the Tirupatur taluk, Salem district. These veins vary in thickness from mere strings to dyke-like masses several feet across, and through them all the barytes is apparently uniformly distributed. The quartz and barytes are considered to be normal original constituents, which have separated from an injected mobile magma like many commoner pegmatites of a different composition; but no evidence is forthcoming concerning the temperature of the magma prior to consolidation. There are none of the "banded" and "comby" structures of mineral veins, and no signs of possible derivation by pseudomorphism from ordinary pegmatite.

Note on a worn femur of *Hippopotamus irravadicus*, Caut. and Falc., from the Lower Pliocene of Burma, by FRITZ NOETLING, PH.D., F.G.S. Palæontologist, *Geological Survey of India* (with Plates XIX and XX).

While mapping the country around the petroleum field of Yenangyoung I discovered on the eastern side of the Yenangyoung anticline, about 50 feet above the ferruginous conglomerate (zone of *Hippotherium antelopinum* and *Acerotherium perimense*), and about half a mile to the north from the place where the flints[1] were found, a remarkable bone sticking out from the face of a low cliff. There was no doubt that this bone was *in situ* when found by me, and that it was in an undisturbed position, there being no signs that it had been touched; in fact, it took some time to free it from its resting place.

At this place a few layers of ferruginous conglomerate are formed above the zone of *Hippotherium antelopinum*, interstratified in the soft yellow sandstone. These layers of conglomerate are sometimes only a few inches in thickness, and a few feet in length, dying out rapidly in any direction and forming therefore patches of smaller or greater extension in the sandstone.

The composition of some of these patches is a peculiar one; they are made up

[1] Rec. Geol. Surv. Ind., 1894, XXVII, pp. 101-103.

Fig. 1.

Fig. 1 a.

Fig. 1 Hippopotamus irravadicus. Lyd.

Fig. 1

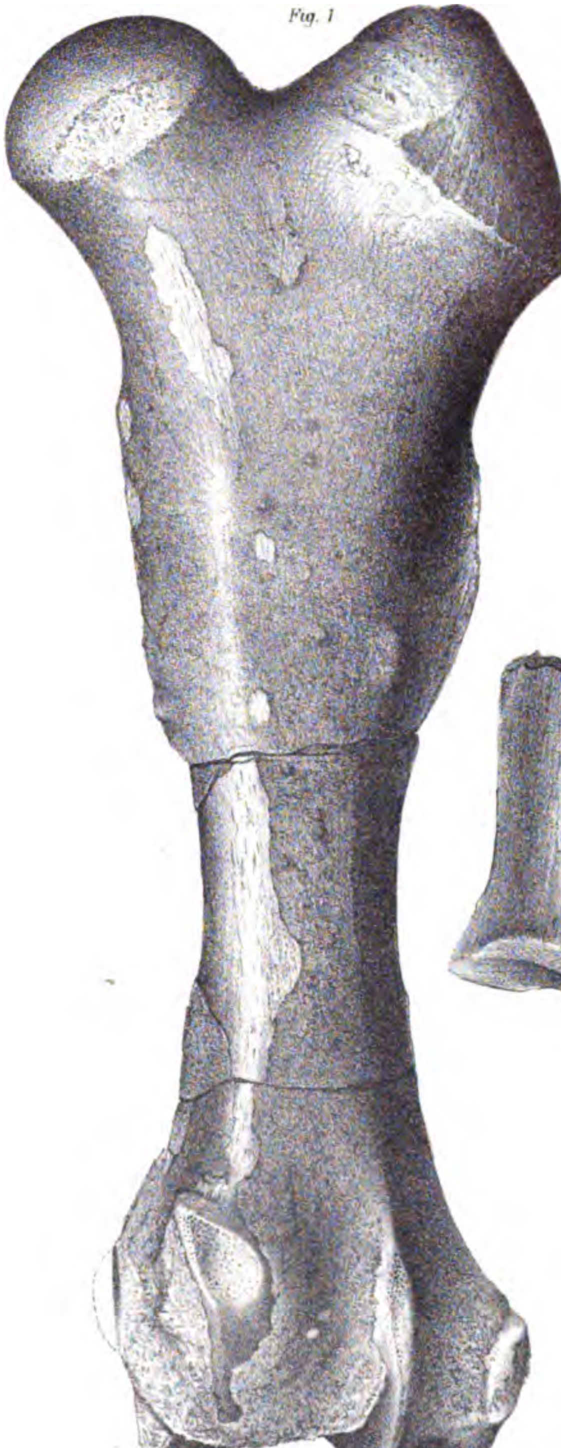


Fig. 2

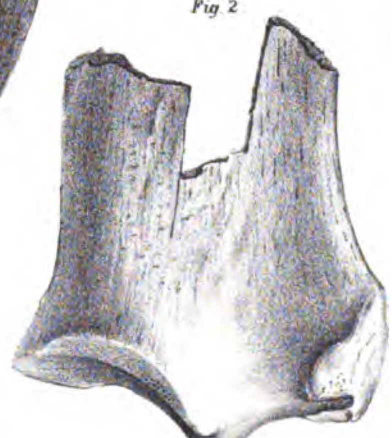


Fig. 1 Hippopotamus irravadicus. Lyd.

Fig. 2 Equus sp.

of small pieces of drift wood fossilized into hydroxide of iron, small pebbles of white quartz, or of a ferruginous claystone, and rolled fragments of bones all mixed up together in a heap exhibiting exactly the features of a heap of shingle on the sea-shore, and it was in one of these that I discovered the femur which is the subject of this paper.

It was resting horizontally on its posterior side, lying flat, with the polished faces of the distal end directly on a layer of soft sandstone. The shingle was heaped around it but did not fully cover it. I distinctly remember that the bone had not sunk into the underlying bed, but was resting flatly on it, and I also recollect that I was particularly attracted by its remarkable position. In taking it out from the rock, a peculiar loss of substance on the ventral side of the distal condyles, where two large flat facets had been formed, at once attracted my attention, particularly as the bone was resting with these two facets on the underlying bed.

This struck me as something very peculiar, particularly as I never noticed anything similar in any of the hundreds of fragments of bones or better preserved specimens I collected around Yenangyoung. I may at once remark that I carefully looked through the Siwalik remains in the collection of the Geological Survey, but not a single specimen exhibited similar defects. It is therefore beyond doubt that whatever the verdict may be as to the origin of these curious facets, the specimen here described is at present unique.

In my paper on the tertiary system of Burma,[1] I mentioned this find for the first time. and this is what I said " A femur of probably *Rhinoceros* sp. which I found in one of these layers affords an exceedingly good illustration regarding the conditions under which they were formed. It rested with one side on a bed of sandstone and around it, and partly over it were heaped ferruginous clay—pebbles, etc., etc., now that side on which the bone rested was considerably rubbed, thus indicating the result of friction on the underlying sand, produced by the gentle rocking of the bone by the waves while lying on the beach."

It subsequently struck me that this was not quite a satisfactory explanation, but as I shall deal with this question presently, it may be left for a while. Though the peculiar feature of the femur struck me therefore at once, I refrained from making it the basis of some, perhaps, too far reaching conclusions until I noticed in the Neues Jahrbuch[2] that Professor Dames had described and figured a scapula of *Equus* the proximal end of which exhibited a similar loss of substance to the femur found by me. Professor Dames unhesitatingly attributes this loss of substance to human agency.

In the controversy which arose as to the origin of those curiously shaped flints, I discovered in the zone of *Hippotherium antelopinum* and *Acerotherium perimense*. I had quite lately an opportunity[3] of giving as extensive a description of the history of the find as possible, and at the end of my paper I mentioned the femur as being probably an additional witness for the origin of the chipped flint flakes, provided the theory held by Professor Dames as to the artificial origin of the loss of substance noticed in the shoulder blade of the diluvial horse was accepted.

[1] Records, Geol. Surv. of India, 1895, Vol. XXVIII, page 77.

[2] Neues Jahrbuch, 1896, Bd. I, page 224.

[3] On the discovery of chipped flint flakes in the Pliocene of Burma, Natural Science, 1897, Vol. X, page 2334.

Having returned from furlough, I am now in the position to give an accurate description of the femur and its peculiar features, and I leave it to the reader to judge for himself.

A careful examination of the femur has proved that it certainly did not belong to either of the genera *Mastodon*, *Elephas* or *Rhinoceros*; the greatest probability was therefore that it belonged to the genus *Hippopotamus*. As far as I can judge from the figures of Blainville and Cautley and Falconer, the general features of the femur agree very well with those of the left femur of *Hippopotamus*, but there are certainly differences, which render it almost certain that it could not have belonged to any species there described, and that with great probability it belonged to *Hippopotamus irravadicus*, the species so clearly described by Messrs. Cautley and Falconer.

The bone measures from the middle of the distal condyles to the top of the great trochanter 600 mm. in length; the great trochanter is very large and rises above the level of the caput. The small trochanter is not very salient, rather a mere rough ridge.

The posterior or ventral side of the condyles exhibits a remarkable loss of substance; on both condyles a flat irregular facet has been formed, measuring about 50 mm. in length in axial direction. It has to be noticed that both facets do not lie in the same plane, but if the internal facet is considered as level, that on the external condyle forms an angle of about 10° with the former. On turning the femur round it will be noticed that there is also a great loss of substance on the internal side of the internal condyle;—in fact, both these worn surfaces if produced would meet at an obtuse angle on the posterior side of the internal condyle. On the anterior or dorsal side the condyles exhibit also two elongate facets; that of the internal one forming an angle of about 30°, that of the external one an angle of about 60° with the ventral facet of the internal condyle.

On turning to the proximal extremity, traces of wearing are seen both on the great trochanter and on the caput; on the great trochanter they assume such a shape as if it had been attempted to attenuate it; on both sides on the anterior as well as on the posterior side, particularly on the latter, these traces are seen.

The anterior side of the caput shows a slight trace of a facet, which is however not distinctly seen.

To sum up, the facets are exhibited on the anterior and posterior side of both extremities in such a way that they run parallel to the axis of the shaft; no facets or any other traces of wear and tear are either noticed on the shaft or on the proximal or distal face.

From the above description it is evident that this femur exhibits at both extremities, particularly on the distal one, traces of a peculiar kind of grinding. As the planes of the facets thus produced are not altogether parallel or in the same level, it is beyond doubt that those on one side cannot have been produced simultaneously, but that they must have been formed consecutively; it is quite irrelevant which was formed first; it is sufficient to know that the position of the facets proves that during their formation the bone must have been submitted to some sort of a revolving action; to form those of the distal extremity, the bone must have been turned at least five times, and whatever the medium may have been that produced the facets, it is quite evident that at one time the bone exhibited its anterior side to

the grinding process and then was turned over, exhibiting its posterior side to the same action. It may be remarked that, judging from the wearing, the process acted more vigorously on the posterior than on the anterior side.

The question now arises, how are these facets to be accounted for; were they the result of the operations of art or of those of nature? Should they be considered as intentionally wrought, are they only the result of a mere accidental process of nature resulting in loss of substance?

If we were able to answer the first question in the affirmative, then there ought to be no longer any doubt that in these facets we have the handiwork of some rational being which lived during the lower pliocene.

It may at once be said that the purpose for which these facets were made, supposing for the moment they were artificial, has no bearing on the question of their origin. For all we know, they may be the result of an idle hour after a good meal. Professor Koken at Tübingen showed me a stag's horn from the diluvial travertine of Taubach near Weimar which had been marked all over in an apparently useless manner. No doubt can exist it was human agency which produced these marks, but it is difficult to see to what purpose, unless we assume that the diluvial man who produced these marks perhaps tried to cut off some of the tines by means of his rude stone celt, and finding that it did not suit his purpose, idly hacked away at the useless bone.

It must not be forgotten that the so-called savage tribes have plenty of spare time, and I personally can state that I often observed in Kachin villages full grown men playing with a piece of wood or a stone to no purpose whatsoever. By grinding such an object on a hard surface a few hours could be pleasantly spent. There is also no doubt that children use their play-things in all sorts of manners, and a good deal of amusement results from sharpening a piece of wood or metal or bone on a stone. Although we may dismiss the notion that the heavy femur here described has been a child's plaything, we may take it as granted that the seemingly meaningless procedure resulting in the production of the facets bears no value on the decision of the question, whether they were made intentionally or were simply the result of an accidental process.

It will therefore be well to discuss first the possibilities by which in a natural way loss of substance in the above described state could be produced. The first theory which would present itself would be to attribute the loss of substance to a chemical process; to the dissolving action of some acid for instance. The question to be considered would therefore be, is it possible that by a chemical process such sharp facets on the extremities could be produced without damaging the rest of the bone. I should think that such a theory affords some serious difficulties; we have to imagine that the bone was imbedded in some substance impermeable to acids; only that small part which was to be worn off sticking out from the protecting substance. After this part had been removed, the bone was turned over, every part of it was again imbedded in the protecting substance except the one to be worn away, and so this process was repeated at least five times to produce the facets of the distal end. To imagine that while these frequent changes took place no other part of the bone should have been affected, seems highly improbable. It will certainly be admitted that if due to chemical action, the facets would probably not exhibit that fine smooth surface, but a more irregular corroded appearance.

I cannot imagine any chemical process which simply by itself without any outside assistance would produce such evenly polished surfaces at special parts of a bone. Were a bone submitted to any chemical action, I should think that its traces ought to be visible all over the surface and not restricted to certain parts. We may therefore dismiss the theory of chemical action.

The facets must therefore be the result of a mechanical action, and it remains to be seen what natural causes might have the effect above described.

The most plausible explanation is of course the action of ice as glaciers produce scratched boulders exhibiting sometimes even faces, the result of a considerable loss of substance. It is therefore by no means impossible that a strong bone such as a femur might be treated in a similar way, although I do not know of any instances which have been noticed. The possibility however must be admitted.

Is there now any trace of glacial action to be noticed in the pliocene formation of Burma? This question may be safely answered in the negative. In fact, if anything, it tends to prove that the pliocene of Burma was deposited under tropical conditions. It may be argued that some of the higher hills existing while the Irawadi series was deposited were covered with glaciers, and that the femur may have been transported from there to the place where it was eventually found. But even granted that the glaciers did exist, such an assumption would require that the individual of *Hippopotamus irravadicus* to which the femur belonged moved in a hilly country in a neighbourhood of glaciers, an assumption which is so contrary to all we know of the habits of *Hippopotamus* that we may safely dismiss it. But even if such a theory would be admitted, the femur should have suffered much more by transport; it could not possibly have retained its fine state of preservation, after it had been exposed firstly to glacial action and then to a journey in streams and rivers before it came to the place where it eventually found its resting place.

The next theory would be to explain the forming of the facets by the mechanical action of running water.

The action of the running water can certainly result in a considerable loss of substance, as need hardly to be mentioned. If we examine however, all water worn objects, we notice that the action of the water tends to produce a more or less rolled shape, and generally an even polished surface. Whatever the original shape of the object may have been, and whatever the substance may consist of, the action of running water always produces the same rolled shape.

It cannot well be imagined that a large bone, like the femur described, would have been mixed up with pebbles, all of a harder substance than itself, and still have retained its perfect shape while all the pebbles were rounded off. Of course, one could suppose that the femur was well jammed in between some larger pebbles or in the rocky bed of a stream; it is under such an assumption quite imaginable that the grinding action of the sand moved over it could eventually have produced the facets. But if, on the other hand, they were really produced in such a way, it is very difficult to explain why the bone should not have suffered later on when it was moved from its resting place. The perfect undamaged shape of the femur proves in my opinion that it never was associated with larger pebbles, nor that it could have undergone a longer transport in a river. If we are right in judging from the habits of the present *Hippopotamus* those of *Hippopotamus irravadicus*, we may perhaps conclude, that the femur was originally deposited on the muddy or sandy beach of a river, perhaps partly imbedded in the soft material, only the

condyles sticking out. The question may then be raised whether the constant run of the water containing a lot of fine silt suspended, such as we notice in all tropical streams during the rainy season, has a sufficient amount of mechanical energy, to grind down of facets as above described. I cannot trace any actual observations for such a view, but I think some unquestionable proofs would be required before it could be accepted. So far, therefore, the loss of substance and the production of the facets cannot be explained by the mechanical action of running water.

The way in which the femur was deposited when I discovered it suggested at first an idea which I afterwards discovered to be an obvious impossibility. I originally believed that the specimen was lying amongst a heap of material such as is gathered frequently on a slightly inclined beach. I imagined that the action of the waves rolling ashore set the femur into a rocking motion which was sufficient to grind down the condyles producing the facets. I overlooked however a very serious objection: first, the tendency of the rocking action of the waves would be a rolling and not a grinding one, as may be noticed at any sea beach; secondly, the way in which the bone was found proves that it was resting on a sandy ground which at that time must have been soft and loose. Facets as those described could however certainly not be produced when the bone was moved by the waves while its bed was soft and yielding. Only the friction against a hard unyielding material could have produced facets, and the above view can therefore no longer hold good.

If the view of the mechanical action of ice or water cannot be sustained, the only natural action remaining which would result in loss of substance would be the action of sand blown by the wind, deflation, in fact. The facetted boulders found at numerous places, the shape of which is generally attributed to the above cause, are well known. The femur resting on a sand-bank in the river, partly imbedded in the sand, might very well have been exposed to such an influence. If the facets existed on one side only, say, for instance, the posterior one, I would unhesitatingly accept this view. But they exist on the anterior side as well, and in such a way that they could not have well been produced simultaneously. Accepting the theory of the blown sand for a moment, we have then to suppose that the facets were first produced on one side, then the bone was completely turned round so as to exhibit the opposite side, which must have been shifted once. It was then again so well imbedded that nothing but a small portion was exposed.

If this theory be accepted, of course the question is settled at once; I want however to point out a serious objection. I cannot well imagine how the movements required were carried out without exposing more than insignificant portions of the surface. In fact the facets on the anterior side are quite incompatible with this view; if they were the result of the action of blown sand, much more of the condyles should have been removed. I find a very serious difficulty in the smallness and the distribution of the facets, as I should think that, had the bone undergone this process, it would have suffered more.

In conclusion, I may mention that the view of these facets being produced by the gnawing of some wild animals is absolutely untenable. No animal could produce even surfaces, such as those described, with its teeth; there would be irregular ragged furrows, but no smooth facets if the femur had been treated by one of the large carnivorous animals.

I think that it is clear from the above arguments that to whatever known natural causes we may look as likely to produce facets as described, we meet always with some serious objections.

If, on the other hand, we suppose that the facets were intentionally made by some being, whether man, ape or *Pithecanthropus*, by holding the bone in his hands pressing it against a hard surface and grinding it down, the manufacture of the facets is easily explained.

We arrive therefore at the result that the whole state of preservation of the femur turns rather in favour of the facets being intentionally produced than accidentally. I wish however at once to say that not for a moment do I contend that the facets *must* be man's handiwork, and that there is no other cause capable of producing them. All I contend is, that very serious objections are connected with the assumption of the production of the facets by natural or accidental causes but if any one can give me any other plausible explanation, free from objections, I am quite willing to forego the conclusion that the facets are the result of the operation of an artificial agency.

Should a satisfactory explanation come forward, I think that specimens exhibiting similar loss of substance should be carefully re-examined, as to the process which caused such a loss. Professor Dames describes and figures a scapula of a horse, stated to come from the diluvial deposits of Northern Germany, exhibiting a similar, and apparently quite meaningless, loss of substance at the proximal extremity. Professor Dames unhesitatingly attributes it to human agency, but in this instance there are in fact more serious objections to such a theory than to the bone from Burma. It is quite true man has lived in diluvial times, while similar proofs are not so absolutely certain and unchallenged with regard to the pliocene period, and a bone exhibiting such features as the one described by Professor Dames and coming from diluvial beds, might only be regarded as a further instance of the existence of man during that period.

But on the other hand the history of the find is much less open to doubts in the case of the bone from Burma than in the case of the diluvial bone. The author did not find the bone himself; it was brought to him: questions may therefore be raised—did it really come from diluvial beds, and if so, was the loss of substance not produced by the tools of the workmen while unearthening it? Professor Dames holds that neither has been the case, but all the same these objections may be raised, and it will be difficult to disprove them.

In the case of the femur here described, no such objections can be raised: there were no working men which could have hurt the bone, and it was *in situ* when found by me in such a place that all ideas of subsequent influences can safely be dismissed. In fact, if one thing is certain, it is that the loss of substance was produced previously to the interment of the bone.

Not only may the above two objections be raised with regard to the diluvial bone; it may also be argued that, being found in strata, the glacial origin of which is no longer doubted, the loss of substance may be attributed to glacial action—a view which certainly does not enter into the question at all with regard to the femur from Burma. It is true that scratched boulders have hitherto not been found in the diluvial gravels in which the scapula is said to be found, but this is no proof against the view that the loss of substance may be the result of glacial action.

In fact if, weighing all the evidence in favour and against the artificial origin of the loss of substance in the case of the diluvial scapula, the evidence against it is rather stronger than for it—but nobody seems to have questioned the view held by Professor Dames with regard to this scapula,—may it therefore not be argued that what is accepted in this instance, also holds good for a bone exhibiting similar loss of substance, but coming from pliocene strata?

Explanation of plates.

PLATE XIX.—Fig. 1. *Hippopotamus irravadicus*, Caut. and Falc. Left femur posterior (ventral) side, ¼ nat. size.

Fig. 1a. Ditto ditto ditto. Distal extremity, ¼ nat. size.

PLATE XX.—Fig. 1. *Hippopotamus irravadicus*, Caut. and Falc. Left femur, anterior (dorsal) side, ¼ nat. size.

Fig. 2. *Equus*, sp. (copy from Neues Jahrbuch, 1896, Bk. I, p. 224) reduced to ⅔ size.

On the Supposed coal *at* Jaintia, Baxa Duars: *By* H. H. HAYDEN, B.A., B.E., *Officiating Deputy Superintendent, Geological Survey of India.*

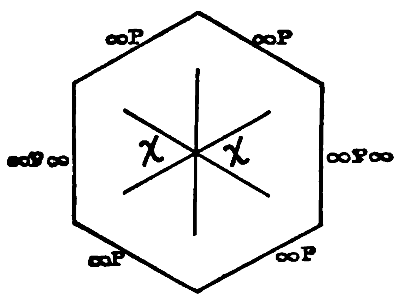
While at Kuch Bihar I was asked by Mr. D. R. Lyall to visit, if possible, the supposed coalmines near Jaintia, on the borders of Bhutan. I therefore took the opportunity, when at Baxa, of making an excursion to the spot. It is highly inaccessible and can only be reached on elephants, either from a point a few miles south of Santrabari, or from Santrabari itself. From Santrabari there is a jungle-path to Jaintia, the distance being about 8 miles. The supposed coal, which is really lignite, is found in the valleys to the north and north-east of Jaintia: the locality visited by me being about 2 miles to the E. N. E. of the village of Jaintia. Here the lignite occurs in bluish-grey and yellowish sandstones of tertiary age, which dip mostly at high angles to the S. W., but the dip is variable both in direction and amount, though always steep.

In some cases large areas—200 or 300 ft. long by 50 to 100 ft. wide—have been exposed on the plane of bedding, and the true character of the deposit is made evident. It consists of a sandstone (probably estuarine) containing isolated logs of lignite. The wood had evidently floated down the rivers and, becoming water-logged, had sunk in the estuaries, where it was embedded in the sand.

This lignite, according to an analysis made by Dr. Saise, is of very good quality, having only a small percentage of ash: but the isolated manner in which it occurs renders it of little value, and for the purpose for which I was informed it was intended, *viz.*, as the fuel supply for a railway, it would be useless. The sandstone which flanks the hills for many miles in this neighbourhood, appears to contain everywhere a certain amount of the lignite, but too scattered and in too small quantities to be of any economic value, particularly in the face of such difficulties as are presented by the inaccessibility of the locality.

Percussion Figures *on* Micas, *by* T. L. WALKER, M.A., PH.D., *Assistant Superintendent, Geological Survey of India.*

A short time ago, I called attention[1] to some points in regard to the percussion figures formed on plates of mica by applying the point of a large needle to a cleavage fragment and striking a sharp blow with a small hammer. The figure resulting is illustrated below. All micas agree in having six-rayed percussion figures whose rays meet at angle s varying from 51° to 64°. It was generally supposed that the rays are parallel to the edges formed by the basal plane (o P) with the prism (∞ P) and clinopinacoid ∞P∞.



After measuring the percusssion figures on some twenty representative micas I found that this is not the case. The measurements then made were published[1] and shewed that the angles of the percussion figure opposite the clinopinacoidal edge, designated χ for convenience, varies from 52° 53′ to 63° 28′. As the micas are regarded as monoclinic, the four angles of the percussion figure, remote from the clinopinacoidal edge and adjacent to the ray which is parallel to the above-mentioned edge, are equal to one another and are different to the other two angles. It was also observed that the size of the angle χ is more or less characteristic for the species examined.

Muscovite	52° 53′ to 55° 57′
Lithia Micas	59° 12′ to 60° 16′
Biotite	about 60°
Phlogopite	60° 52′ to 63° 28′

Desiring to further investigate the subject I made an examination of all the suitable micas contained in the Indian Museum. I give below the measurements of the angle χ for those micas not previously reported upon. The results in general confirm the conclusions previously arrived at, *viz.*, the rays of the percussion figures are not parallel to the prismatic and clinopinacoid edges, but meet at

[1] American Journal of Science, Vol. II, 1896, p. 5. Observations on Percussion Figures on cleavage plates of mica.

angles varying from 51° to 64° which are more or less characteristic for the different mica species.

	°	′
Muscovite.—Hazaribagh, Bengal	51	49
" Alstead, N. H., U. S. A.	52	3
" Hazaribagh, Bengal	52	42
" Miask, Urals	52	50
" Gaya, Bengal	52	52
" Narsinghpur	53	17
" Vienna Exhibition (locality ?)	53	25
" Nellore District, Madras	53	30
" Goshen, Mass., U. S. A.	54	30
" Pennsbury, Pa., U. S. A.	54	30
" Nawadi, Bengal	54	35
Euphyllite.—S. Rewah, Central India	54	45
Muscovite.—Alstead, N. H., U. S. A.	54	47
" Garhwal, N. W. P.	54	53
" Hazaribagh, Bengal	54	55
" Sirmur State, Punjab	55	0
" Sutlej River, N.-W. Himalayas	55	16
" Darjeeling, Bengal	55	27
" Tonk, Rajputana	55	57
" MacDonald Range, S. Australia	56	25
Lepidolite (?).—Paris, Me., U. S. A.	54	58
Rubellan.—Eifel, Prussia	59	28
Lepidomelane.—Wermland, Sweden	about 60.	
Biotite.—Alstead, N. H., U. S. A.	ditto	
" Greenland	ditto	
" Lake Baikal, Siberia	60	15
" Hazaribagh, Bengal	60	18
Phlogopite.—S. Mirzapur, N.-W. P..	59	20
" Burma (in crystalline limestone)	60	23
" Travancore State	63	14

Notes from the Geological Survey of India.

Elæolite at Sivamalai.—An interesting discovery of elæolite-bearing rock has been made at Sivamalai in the Coimbatore district where the Sivamalai hills near Kangayam are composed of a fine grained elæolite-bearing rock, darkened by the presence of magnetite, graphite and ferro-magnesian silicates, amongst which biotite and hornblende prevail. This is cut through by veins of coarse grained rock in which the crystals of elæolite reach a diameter of 4 inches. This elæolite-bearing rock is associated with a pink pegmatite, practically devoid of quartz and containing crystals of corundum, which occurs as veins in and near the boundary of the elæolite-bearing rock. Mr. Holland has suggested that we may here look to the elæolite as the source of the alumina, of which it contains over 33 per cent., and especially points to the fact that the Sivamalai corundum has the crystal habit of Lagorios pyrogenic corundum (Zeits. f. Kryst, XXIV, 285). The field evidence is certainly consistent with the theory that the pegmatite, penetrating and absorbing the elæolite-bearing rock, acquired an excess of alumina which subsequently crystallised out as corundum.

Earthquake of 12th June.—A large number of reports have come in during the last quarter, and as one result it has been found that the area over which the shock was felt must be extended to include the whole of the Irawadi valley and delta. To the east of the Pegu Yoma, the only place from which it is reported is Pyinmana. An important report has been received from the Superintendent of telegraphs, Assam, describing how, when communications from Shillong were being reopened, it was found that, so long as the earth was used as a return, the operator was subject to electric shocks, some of considerable severity, which always accompanied one of the earthquake shocks which were constantly occurring. This, as well as the frequent interruptions of communication which accompanied the shocks, ceased as soon as a second wire was used as a return instead of the earth.

At the Magnetic Observatory at Bombay perturbations of the self-recording magnetic instruments were noticed, which it is difficult to ascribe entirely to mechanical causes, but the time at which they occurred renders it impossible for them to have been directly connected with the electric disturbances at Shillong, and if magnetic or electric at all, they must have been such as a secondary result of the mechanical effect of the earthquake wave in the immediate vicinity of Colaba.

31st October 1897. R. D. OLDHAM.

Selection from the Assays and Examinations made in the Laboratory of the Geological Survey of India between November 1894 and November 1897.

Date.	Substance.	For whom.	Result.
13-XI-94.	One specimen of impure limonite, found in and about Mahableshwar, in the Satara District.	The Under Secretary to the Government of India, Revenue and Agricultural Department.	*Quantity received*: 1½ oz. Contains 46·46 per cent. of iron (Fe).
19-XI-94	One specimen of quartz, with copper pyrites, from the North Arcot District.	Edgar Thurston, Superintendent, Government Central Museum, Madras.	*Quantity received*: 4¾ oz. Contains a trace of gold.
26-XI-94	One specimen of galena, from a hill 1 mile north-west of village Dhanpur, Kumaon.	Colonel E. E. Grigg, Commissioner of Kumaon.	*Quantity received*: 2lbs. 6 oz. Yielded on assay, 66·30 per cent. of lead; and 1 oz. 12 dwts. 6 grs. of silver to the ton of lead.
4-1-94 .	One specimen of iron pyrites, with quartz and slate, from Gohna.	Colonel D. G. Pitcher, Department of Land Records, Gwalior State.	*Quantity received*: 1 lb. Contains a trace of gold.
20-XII-94	One specimen of white earth, from Afghanistan.	C. W. Walsh, Martin & Co., Calcutta.	Lithomarge, allied to Fuller's earth, with some pieces containing graphite.

Date.	Substance.	For whom.	Result.
3-XII-94	Specimens collected in Eastern Persia.	Surgeon-Major G. W. Brazier Creagh.	The majority are from the mountains Taftan, Basman, Hamant and Fanach.

Taftan is an active volcano from which sulphur and sal ammoniac were obtained. *Basman* is volcanic, but not now active. Sulphur was also obtained here. *Hamant* and *Fanack* doubtful. (B.—C.)

No. I. Salt from Tank-i-Nimak, North of Amadi, 6 stages N. of Bandar Abbas. The nala is white with salt.

Tombstones from an old cemetery in the Kosh Valley under the lofty Taftan, an active volcano. Inscriptions supposed to be very old. (B.—C.)

No. II. A. Specimens from Fanach hill. Elevation 4,860 feet.

Amongst the rocks are specimens of a partially decomposed troctolite (originally an olivine plagioclase rock). The other specimens are red clay with partings of calcite, lumps of limestone, pale green epidote and silicified magnesite: probably not far removed from serpentine.

B. Specimens from the rocky bed of Fanach pass. Mostly limestones, partly crystalline and in some cases evidently derived from infilled cracks. Specimens of red clay rock are generally silicified, but cracks are also filled in with calcite. These and the green rocks resemble volcanic ash beds. One specimen is a mixture of quartz and light green epidote.

No. III. Fragments of limestone and quartz from hills between camp Abgar and Itchan. Elevation 1,900 feet.

No. IV. Limestone, partly silicified and dolomitized, from hills between Gordahan and Isfaka.

No. V. Specimens from Hamant hill. Elevation 7,623 feet. Said to be a dormant volcano.

Shales baked and silicified, dolomites and magnesites with veins of calcite, veins of quartz and epidote. Specimens of talcose schist. Specimens of serpentine said to occur in huge masses.

Geh hills. Elevation 1,400 feet.

Specimen of brown marl, with veins of quartz and dirty calcite containing carbonate of iron. Silicified red shale with veins of quartz. Specimen of dark green, compact and well jointed rock containing carbonate of lime, possibly compact ash bed. Specimens of fibrous calcite.

Sand from Bampur Dasht near Geskok Camp. Elevation 1,800 feet. Dirty calcareous quartz sand with semi-rounded grains.

No. VI. "A. Specimens from Koh-i-Cheltan or Taftan or Koh-i-Naushadir (sal ammoniac). Volcanic peak 12,800 feet (approx.)."

Pumice and fragmental rocks (tuffs and ash) of an andesitic volcanic outburst. Considerable quantities of infiltrated calcite in most specimens. Native sulphur with small quantities of soluble sulphates and chlorides.

No. VII. Mak or Lak=a yellowish marl from Cheltan Range, which, with leaves of the Kangak shrub, makes a black dye called Lak-i-Siah, and with leaves of the pomegranate makes purplish yellow dye.

As the specimen sent contains large quantities of sulphate of iron, doubtless it is this substance which combines with the tannic acids of the leaves to produce a black tannate of iron. The aqueous extract of the same substance with pure tannic acid gives a deep blue-black ink. The iron compounds will also, of course, give different colours with other leaves in which the tannic acids are present in a different form.

No. IX. Hill in sandy desert near camp Geskok. Lumps of carbonate of lime (like kunkur) and conglomerate cemented with carbonate of lime.

Date.	Substance.	For whom.	Result.

No. X. A, Specimens of rocks from Basman peak, a dormant volcano. Elevation 11,200 feet.

Andesitic ejectamenta. Andesites with rhombic pyroxenes, as in the case of Koh-i-Cheltan, and with flakes of brown mica. Some specimens fragmental and pumiceous, but of the same family. Lumps of carbonate of lime apparently from infillings of cracks.

B. Sulphur from same locality.

C. Limestone fragments from Koh-i-Alman range, part of Basman. Elevation 4,000 feet.

No. XI. A. Specimens from hills near Basman village. Specimens of hornblende-biotite granitite. Lumps of quartz rock and hardened lithomarge. Specimens of decomposed pumice. Masses of limestone, some pieces well crystallised.

B. Dark calcareous earth with scales of biotite, same locality.

C. and D. Volcanic agglomerate composed of various minerals, fragments of pumice, etc., all impregnated with carbonate of lime and salt.

E. Slab of hornblende-andesite.

Date.	Substance.	For whom.	Result.
15-II-95	Three specimens from the summit of Babar-garh, Waziristan.	H. A. Casson, C.S., Political Officer, Bannu Column, Bannu.	Nos. 1 and 2, basic volcanic agglomerate. No. 3, iron pyrites.
4-III-95	One specimen of clay from the Lameta group, Warora, Central Provinces.	Geo. R. Reynolds, Manager, Warora Colliery.	Contains 83·63 per cent. of Silica (SiO).
20-IV-96	Two specimens from the Kaira District, Gujerat.	J. Walter Leather, F.C.S., etc., Agricultural Chemist to the Government of India.	No. 1, earthy hematite. No. 2, limonite nodules (possibly pebbles) in a matrix of carbonate of lime.
1-III-95	Specimens from the Salem District.	C. S. Middlemiss, B.A., Deputy Superintendent, Geological Survey of India.	No. $\frac{10}{171}$, dunite, partly altered into serpentine. S.G. 2·961. Silica (SiO_2). 36·64% Magnesia (MgO) 46·12% | No. $\frac{10}{8}$, dunite: S. G. 3·176. Silica (SiO_2) 39·1% Magnesia (MgO) 48·26% No. $\frac{10}{117}$, magnetite schist. S. G. 3·538. Contains 36·66% of iron (Fe). No. $\frac{10}{113}$, magnetite schist. S. G. 3·365. Contains 35·00% of iron (Fe). No. $\frac{10}{115}$, magnetite schist. S. G. 3·415. Contains 32·40% of iron (Fe).
6-VI-95	One specimen of coal, containing iron pyrites, from Yenangyoung, Upper Burma.	F. Noetling, Ph. D., Palæontologist, Geological Survey of India.	Moisture . . . . . . 8·54 Volatile matter . . . . . 37·40 Fixed carbon . . . . . 42·80 Ash . . . . 11·26 100·00 Does not cake. Ash—dark greyish red.

<table>
<tr><th>Date.</th><th>Substance.</th><th>For whom.</th><th>Result.</th></tr>
<tr><td>6-VI-95</td><td>One specimen of limonite from about two miles south-east of Jate, Porahat District, Lohardagga Division.</td><td>W. Anderson, Geological Survey of India.</td><td>Contains 36·68 per cent. of iron (Fe).</td></tr>
<tr><td>8-VII-95</td><td>Two specimens of iron ore from Rewah.</td><td>P. N. Datta, B. Sc., Deputy Superintendent, Geological Survey of India.</td><td>A. Manganiferous hematite, limonitic. Foot of Kymore scarp, north-west of Baghwar, near Boorgaona, Rewah. Contains 50·43 per cent. of iron (Fe).
B. Limonite.
Half mile north-east of Sulkma village, Ramnagar Tahsil, Rewah.
Contains 20·47 per cent. of iron (Fe).</td></tr>
<tr><td>12-XII-95</td><td>Galena from a hill about 14 miles east of Madeya, Mandalay.</td><td>H. H. Hayden, Assistant Superintendent, Geological Survey of India.</td><td>*Quantity received*: 2 lbs. 7 oz.
Yielded on assay, 53·42 per cent. of lead; and 4 oz. 14 dwts. 17 grs. of silver to the ton of lead.</td></tr>
<tr><td>12-XII-95</td><td>Quartz from old gold workings at Chinnatha-gannu, Udu, Kollegal Taluq, Coimbatore District.</td><td>C. S. Middlemiss, Superintendent, Geological Survey of India.</td><td>*Quantity received*: 8 lbs.
Yielded on assay, a trace of gold.</td></tr>
<tr><td>10-I-96</td><td>Three specimens of quartz, and one of schist, from Porahat, Chota Nagpore.</td><td>C. L. Griesbach, Director, Geological Survey of India.</td><td>1. "Quartz reef (2)" *Quantity recd.* 10 lbs.
2. "Takraburn No. 4 cutting" " 7 "
3. "Ragolburn hill" " 9 "
4. Schist " 1½ "
Yielded on assay, no gold.</td></tr>
<tr><td>6-III-96</td><td>One specimen of crushed quartz, from 23 miles S.S.E. of Balarampur, Bengal Nagpur Railway, for gold.</td><td>C. L. Griesbach, Director Geological Survey of India.</td><td>*Quantity received* : 19 lbs.
Yielded on assay, 1 dwt. 9 grs. of gold per ton.</td></tr>
<tr><td>10-IV-96</td><td>Seven specimens of crushed quartz, from 23 miles S.S.E. of Balarampur, Bengal Nagpur Railway, for gold.</td><td>W. Anderson, Specialist, Geological Survey of India.</td><td><table><tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td>*Quantity recd.*</td><td>8 lb.</td><td>6 lb.</td><td>4 lb.</td><td>8 lb.</td><td>4 lb.</td><td>4 lb.</td><td>4 lb.</td></tr></table>Contain no gold.</td></tr>
<tr><td>30-IV-96</td><td>Two specimens from Port Blair for determination.</td><td>Major R. C. Temple, Superintendent of Port Blair.</td><td>*Specimen from Flat rock Invisible bank, about 60 miles South East of Port Blair.*
Marine sedimentary organic limestone, with granules of plagioclase felspar and hornblende, derived from some older volcanic rocks; organisms foramnifera, radiolaria, etc. The rock belongs to Oldham's Archipelago series of late Tertiary age.
Specimen found off anchorage at North-West end of Narcondam.
Magnetite sand, with grains of quartz, ilmenite and felspar, evidently derived from the basaltic rocks of Narcondam.</td></tr>
</table>

Date.	Substance.	For whom.	Result.
13-V-96	Two specimens of coal, from Rewah State.	R. D. Oldham, A.R.S.M., F.G.S., Offg. Director, Geological Survey of India.	GARWANI. *Quantity received*: 1 lb. 11 oz. Moisture 2·08; Volatile matter 8·72; Fixed carbon 44·76; Ash 44·44; 100·00. Ash—reddish grey. Does not cake. — SINDHOA, NEAR KARSWA. *Quantity received*: 3 lbs. 3 oz. Moisture 4·60; Volatile matter 26·00; Fixed carbon 41·12; Ash 28·28; 100·00. Ash—grey. Does not cake.
29-V-96	One specimen of auriferous quartz, from the old workings in Kollegal Taluq (Tippoo's Mines), Madras.	C. S. Middlemiss, B.S., Superintendent, Geological Survey of India.	*Quantity received*: 2 lbs. 6½ oz. Yielded on assay, 2 oz. 5 dwts. 17 grs. of gold per ton.
9-VI-96	One specimen of coal, from centre of broadest bands, Mithwa coal-field, about 1½ miles from Thathanah N. N.-W. Upper Burma.	H. H. Hayden, B.A., B.E., Assistant Superintendent, Geological Survey of India	*Quantity received* 8 lbs. Moisture 6·16; Volatile matter 33·48; Fixed carbon 24·64; Ash 35·72; 100·00. Ash—light grey. Does not cake.
10-VI-96	Three specimens of iron ore, from Rewah State.	P. N. Datta, B.Sc., F.G.S., Deputy Superintendent, Geological Survey of India.	1. *Limonite, S. W. of Lukaora.* *Quantity received*: ¼ lb. Contains 35·76 per cent. Iron (Fe). 2. *Limonite, ½ mile N. by E. of Paujerio H. S.* *Quantity received*: 14 oz. Contains 48·75 per cent. Iron (Fe). 3. *Hematite, near Puri, S.-W. of Hurma on the Son.* *Quantity received*: 11 oz. Contains 44·32 per cent. Iron (Fe).
30-VI-96	A specimen of limonite concretion, from Nyaungnigyin, Pagan district, Upper Burma.	H. H. Hayden, B.A., B.E., Assistant Superintendent, Geological Survey of India.	*Quantity received*: 4½ oz. Contains 44·12 per cent. Iron (Fe).
14-VIII-96	One specimen of quartz, from Balarampur, Manbhum district.	W. Anderson, Specialist, Geological Survey of India.	*Quantity received*: 78 lbs. Yielded on assay, a trace of gold.

Date.	Substance.	For whom.	Result.
2-X-96	Specimens of amalgam tailings, and blanketings, the result of two trial crushings, of 15 and 9 tons quartz.	W. Anderson, Specialist, Geological Survey of India.	1. *Mohalbana, Manbhum district.* Amalgam, from bottles marked 1, 4 and 7, from 9 tons crushed quartz. Yielded on assay, 1·24 grs. of gold, equal to ·138 grs. per ton. 2. *Chandra Dhobni, Manbhum district.* Amalgam, from bottles marked 2, 3, 5 and 6, from 15 tons crushed quartz. Yielded on assay, ·095 grs. of gold, equal to ·0063 grs. per ton. 3. Tailings, from 9 tons crushed quartz. Yielded on assay, a trace of gold. 4. Tailings, from 15 tons crushed quartz. Yielded on assay, a trace of gold. 5. Blanketings, from 15 tons crushed quartz. Yielded on assay, a trace of gold.
3-VIII-96	One specimen of quartz, from the Singbhoom district.	A. E. Wild, Conservator of Forests, Bengal.	Contains a trace of gold.
14-I-97	One specimen of Lignite, containing plant remains and specks of resin, found at the bottom of a well, 201 feet from surface, Pallana, about 12 miles from Bickaner, Rajputana.	Lieut.-Col. H. A. Vincent, Political Agent, Bickaner.	*Quantity received* : 7 lbs. Moisture . . . . . . 12·50 Volatile matter . . . . . 41·40 Fixed carbon . . . . . 37·50 Ash . . . . 8·60 100·00 Does not cake. Ash—light grey.
5-I-97	Three specimens of minerals, for determination.	Geo. Watt, Reporter on Economic Products to the Govt. of India.	*No. 1.—From Kabul.* Travertine. *No. 2.—From Sakesar and Kalabagh, Punjab.* Massive gypsum. *No. 3.—From Kabul.* Borvenite (Pseudo Jade).
17-XII-96	One specimen of Psilomelane, from Gosalpur, Jabalpur district, for phosphorus.	C. W. McMinn, Jabalpur.	Contains ·589 per cent. phosphoric anhydride $(P_2\,O\,)$.
8-III-97	A white mineral, found underneath the coal strata, Chitteedand, Salt Range, supposed to be Bauxite.	Museum, Geological Survey of India, Calcutta.	S. G. 1·707. SO_3 . . . . 23·63 H_2O . . . . 46·44 Az_2O_3 . . . . 30·08 CaO . . . . trace. Fe_2O_3 . . . . " ZnO . . . . " 100·15 =Aluminite.
8-III-97	Three specimens from Bashahar, supposed to be Sapphire.	R. G. Thomson, C. S., Deputy Commissioner, Simla District.	Amethyst.

Date.	Substance.	For whom.	Result.
10-III-97	Six specimens of coal from the Warora Colliery.	C. O. Leefe, Assistant Secretary to Chief Commissioner, Public Works Department, Central Provinces, Nagpur.	

	"No. 4 pit, Far north district, 3 seam."	"No. 4 pit, rise Bar district 3 seam."	"No. 5 pit, 18 rise, 3 seam."	"No. 5 pit, S. A. R., 2 seam."	"No. 5 pit, Main dip, 3 seam."	"Main dip, 2 seam."
Quantity received.	10lbs.	10lbs.	10lbs.	10lbs.	10lbs.	10lbs.
Moisture	8·40	9·78	26·52	7·40	6·38	10·40
Volatile matter.	29·00	29·62	27·10	20·48	19·64	30·42
Fixed carbon.	42·74	43·72	40·08	36·44	31·62	41·12
Ash .	19·86	16·88	26·30	35·68	42·36	18·06
	100·00	100·00	100·00	100·00	100·00	100·00
	Do not cake.					
	Ash—pale reddish grey.	Ash—reddish grey.	Ash—reddish grey.	Ash—light grey.	Ash—light grey.	Ash—light grey.

Date.	Substance.	For whom.	Result.
11-III-97	One specimen of Galena, from Arki, Baghal State, Simla Hills.	R. G. Thomson, C.S., Deputy Commissioner, Simla District.	*Quantity received*: 2½ lbs. Yielded on assay, 75·17 per cent. lead (Pb); and 21 oz. 1 dwt. 9 grs. silver to the ton of lead.
10-IV-97	Four specimens of coal from Assam.	F. H. Smith, Geological Survey of India.	

	I.	II.	III.	IV.
Quantity received.	5½ oz.	7 oz.	5½ oz.	4½ oz.
Moisture .	5·36	3·88	3·14	7·10
Volatile matter.	49·96	57·52	29·00	37·48
Fixed carbon.	25·32	25·40	15·24	40·38
Ash .	19·36	13·20	52·62	15·04
	100·00	100·00	100·00	100·00
	Sinters slightly. Ash—light buff.	Sinters slightly. Ash—light buff.	Does not cake. Ash—light buff.	Does not cake. Ash—dark reddish brown.

Date.	Substance.	For whom.	Result.
12-V-97	Two specimens of coal, from Assam.	F. H. Smith, A.R.C.S., Deputy Superintendent, Geological Survey of India.	*Quantity received.* A. $10\frac{1}{2}$ oz. B. 4 oz. Moisture . . . 10·74 9·40 Volatile matter . . 31·12 34·42 Fixed carbon . . 25·90 26·32 Ash . . . . . 32·24 29·86 100·00 100·00 Does not cake. Ash—white. Ash—pale white.
18-V-97	One specimen of lignite with specks of resin, from Pallana, 12 miles from Bickaner, Rajputana.	Tom. D. LaTouche, B.A., Superintendent, Geological Survey of India.	*Quantity received*: 45lbs. Moisture . . . . . . 8·20 Volatile matter . . . . . 42·72 Fixed carbon . . . . . 39·48 Ash . . . . 9·60 100·00 Sinters slightly, but does not cake. Ash—light brown. Calorific power in heat units (C), 7,293. Evaporative power, 13·58.
10-VI-97	A heavy metallic looking specimen from the Koderma Government Forest, Hazaribagh District, supposed to be iron.	A. Gow-Smith, Hastings House, Alipore.	Columbite; S. G. 6·19.
9-VIII-97	Pebbles of schist containing quartz, Wa States, Burma, for gold assay.	The Chief Secretary to the Government of Burma, per J.G. Scott, Superintendent of the Northern Shan States, Burma.	*Quantity received* : 14lbs. Contains 10·5 grains of gold to the ton.

Date.	Substance.	For whom.	Result.
18-IX-97	A specimen of the granitite from Uramalia quarry ½ mile S. W. of Karasamir, S. Arcot District. For bulk analysis.	T. H. Holland, Officiating Superintendent, Geological Survey of India.	$Si O_2$ . . . . . 58·30 $Al_2 O_3$ . . . . . 20·76 $Fe_2 O_3$ . . . . . 2·59 Fe O . . . . . 3·84 Ca O . . . . . 8·38 Mg O . . . . . 2·62 $Na_2 O$ . . . . . 4·21 $K_2 O$ . . . . . ·71 Ignition . . . . . ·20 TOTAL 101·61
18-IX-97	A hand specimen of hypersthene, hornblende granite from Perumbakam, Madras. For bulk analysis.	Ditto . .	$Si O_2$ . . . . . 61·40 $Al_2 O_3$ . . . . . 19·38 $Fe_2 O_3$ . . . . . ·58 Fe O . . . . . 5·27 Ca O . . . . . 6·56 Mg O . . . . . 3·24 $Na_2 O$ . . . . . 2·78 $K_2 O$ . . . . . ·44 Ignition . . . . ·15 TOTAL . 99·80
21-IX-97	Alkaline salt from Yenangyat, Upper Burma, where it occurs as an incrustation and is more or less impure.	G. E. Grimes, Assistant Superintendent, Geological Survey of India.	The portion soluble in hot water was analysed separately—the insoluble portion is given below under the heading of "Insolubles." Reaction distinctly alkaline. $Na_2 O$ . . . . . 34·89 $K_2 O$ . . . . . ·24 Ca O . . . . . 1·25 Mg O . . . . . 1·80 $S O_3$ . . . . . 48·09 Cl . . . . . . ·32 Ignition . . . . . 4·65 Insolubles . . . . . 10·00 101·24 Less oxygen equivalent . ·08 TOTAL . 101·16 This analysis shows that the substance contains about 78 per cent. $Na_2 S O_4$, with smaller quantities of $Ca S O_4$ and $Mg S O_4$.